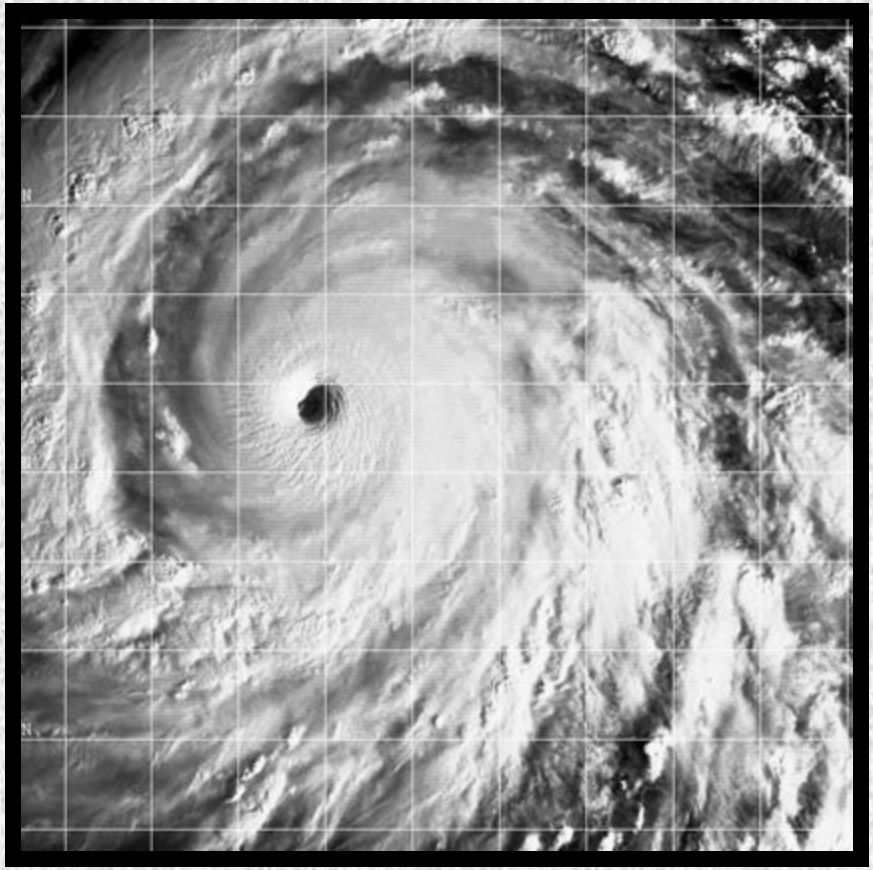
Dvorak Technique

JTWC SATOPS/AFWA XOGM)

- Positioning
- Intensity Estimation
  - Final T-number
    - Data-T
    - Pattern-T
    - Model-T
  - Current Intensity
- Rules



What is the Dvorak Technique?

- A statistical method for estimating the intensity of tropical cyclones from satellite imagery
- Can use both Infrared and Visible imagery
- Based on a “measurement” of the cyclone’s convective cloud pattern and a set of rules

What the Dvorak Technique isn't

- **A direct measurement of wind, pressure, or any other meteorological variable associated with a tropical cyclone!**
- **A replacement for *in situ* measurements of a tropical cyclone**

Step 1 - Locate the Cloud System Center

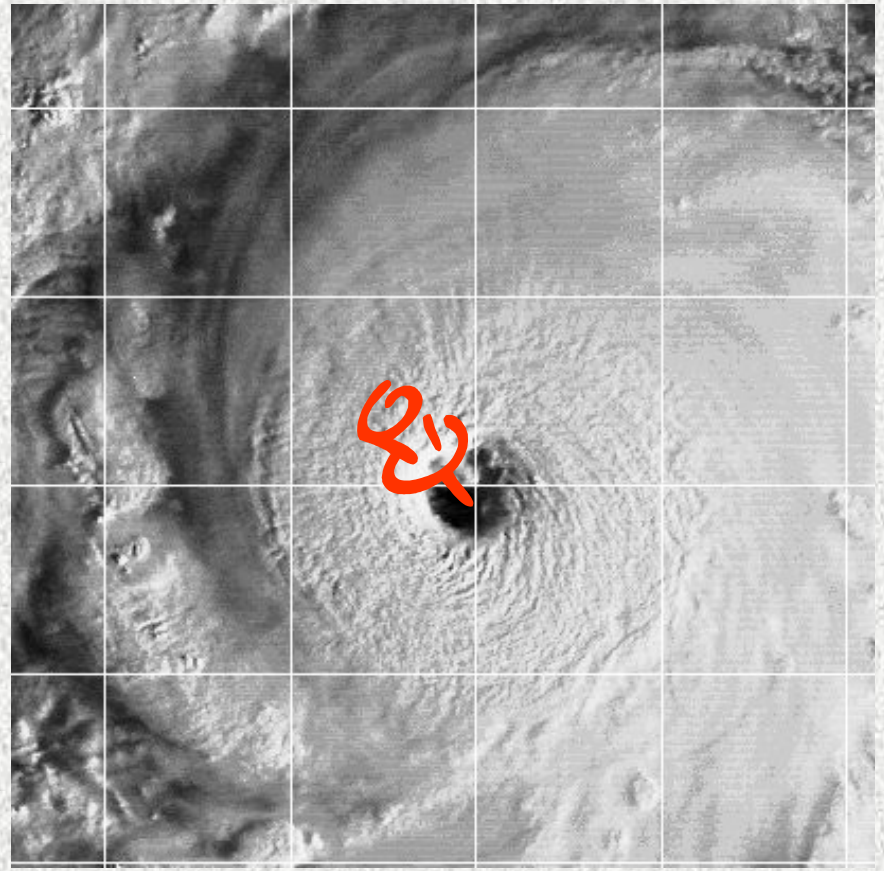
- Locate the Overall Pattern Center
- Examine for Small Scale Features
- Compare Center Location with Forecast
- Compare Center with Previous Pattern Center
- Make Final Center Adjustments
- Looking for Lowest Possible Center

Positioning

- Eye
- Exposed Low Level Circulation Center (LLCC)
- Cold Dense Overcast (CDO)
- Embedded Center (EMB CTR)
- Spiral Curved Band (SBC)
- Partially exposed LLCC
- Cloud minimum wedge
- Central Cold Cover (CCC)
- Cirrus outflow
- Circle method
- Conservative feature
- Animation
- Extrapolation

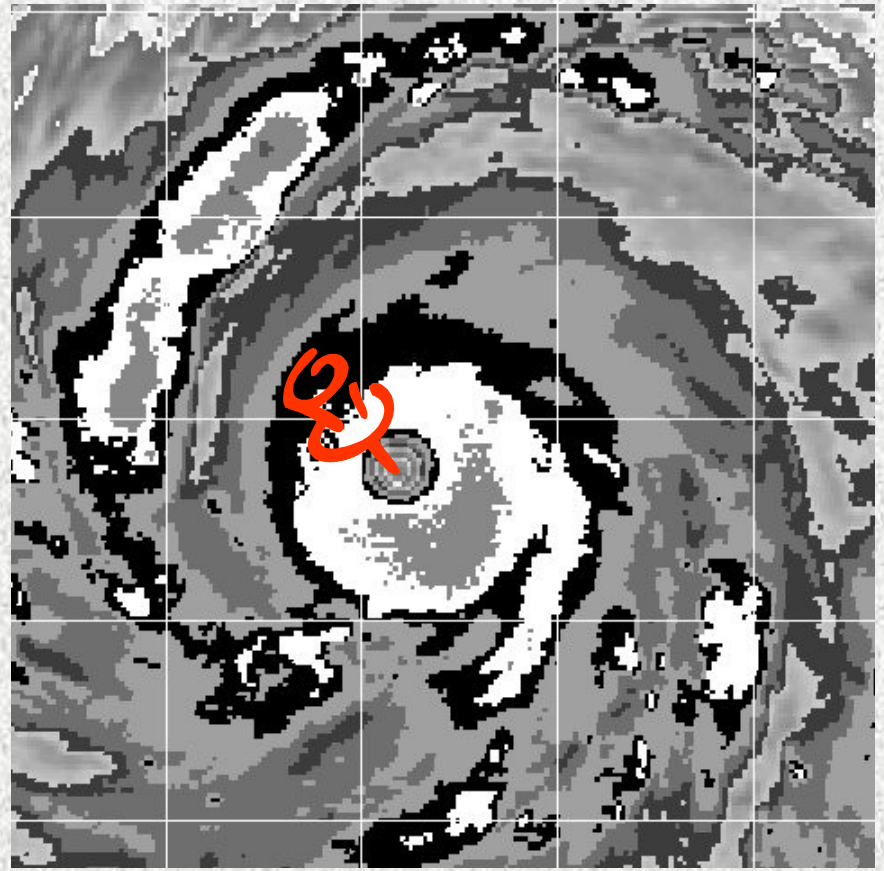
Eye Fixes Visual (VIS)

- Dark cloud free spot
- Shadowy spot for cloud filled eye
- Without LLCC showing within eye, fix on center of eye
- Measure width
- Evaluate shape



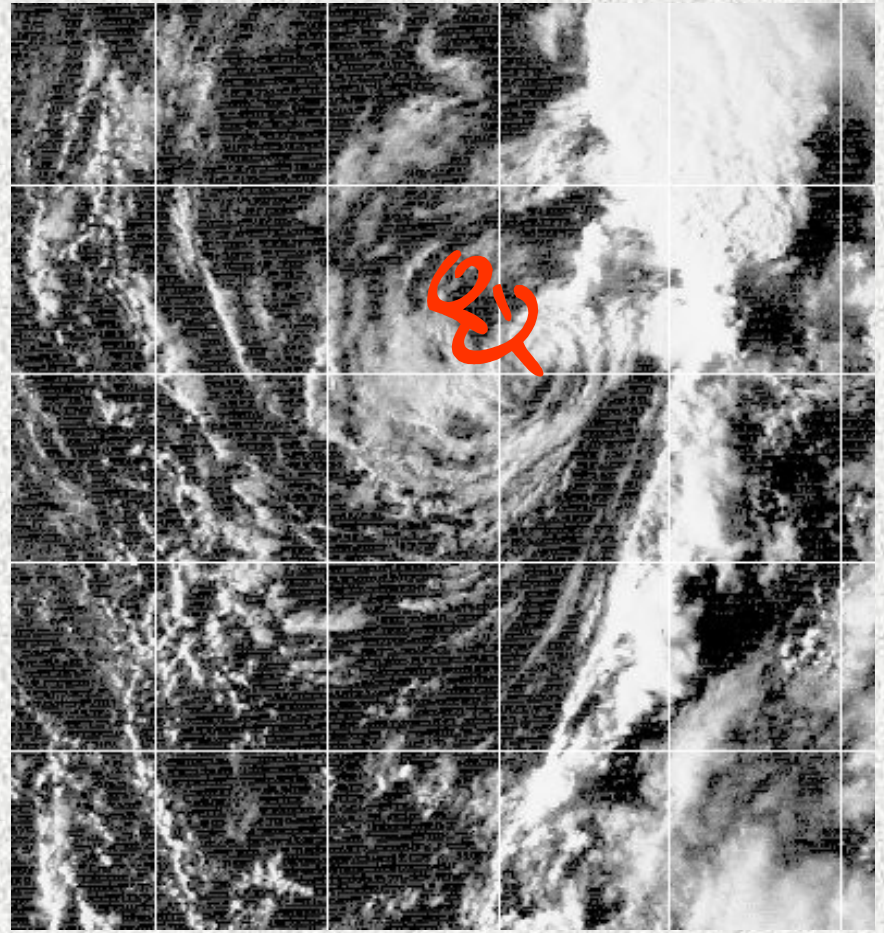
Eye Fixes Infrared (IR)

- Warm spot
  - As a guideline look for 2 shades warmer on the BD curve
  - Eye boundary defined by the tightest temperature gradient
- Measure width without VIS
- Evaluate shape without VIS



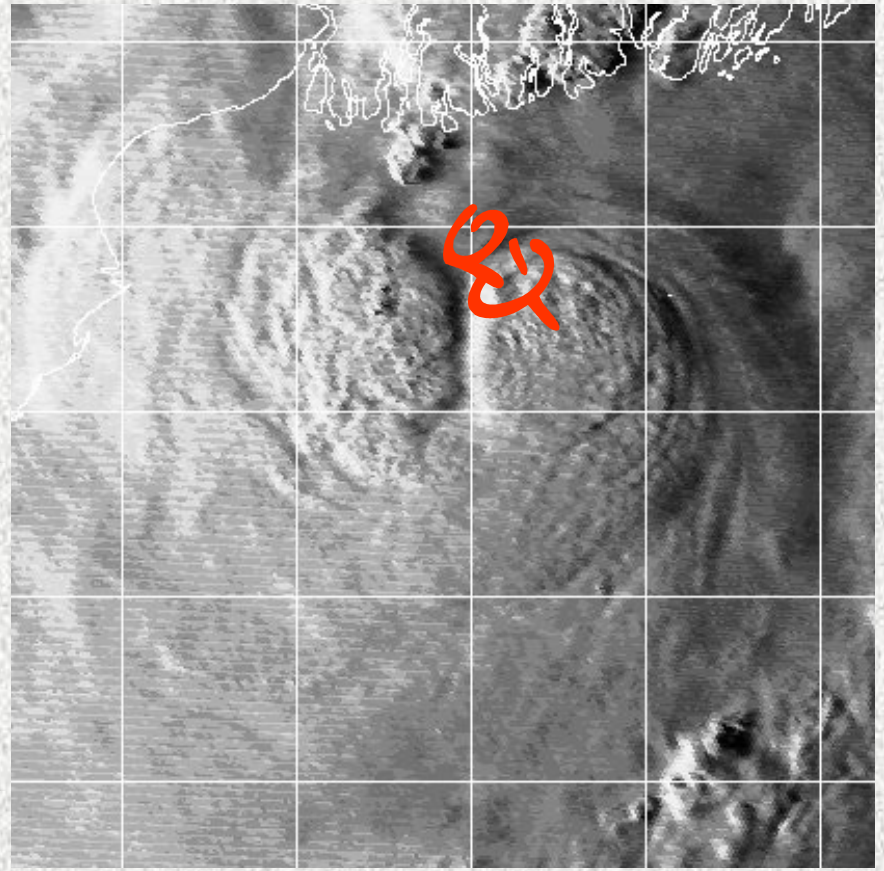
Exposed LLCC Fixes

- Look for tightening cyclonic low clouds.
- The center will be within the tightest circle of clouds.
- Much easier to find with VIS imagery



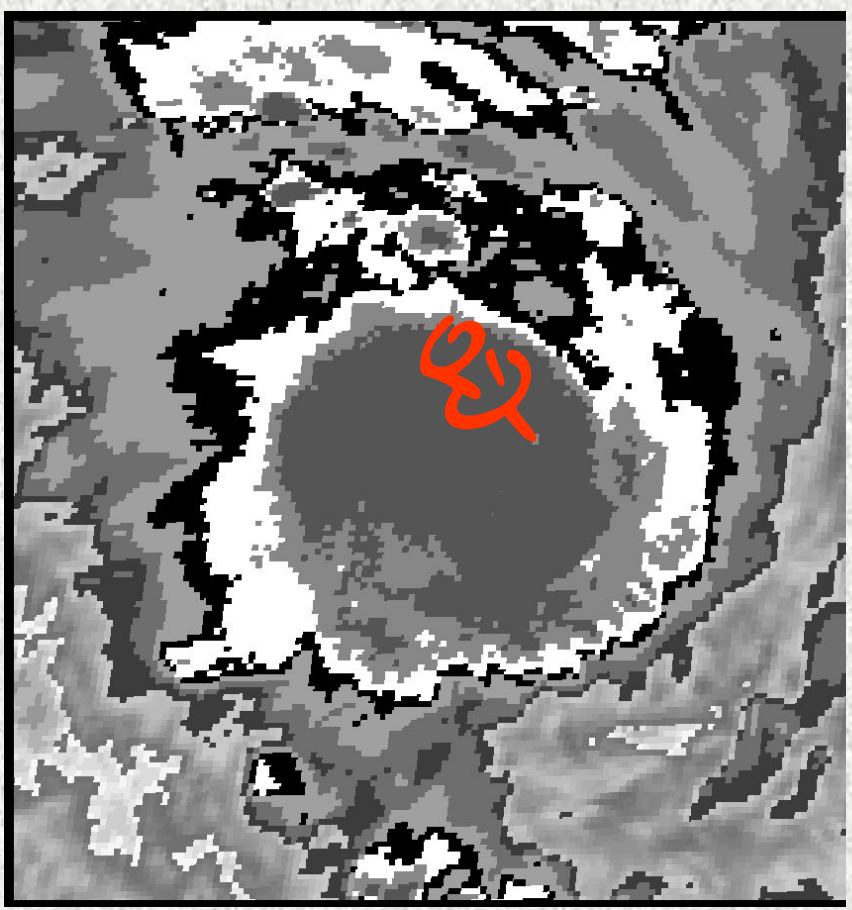
CDO Fixes

- VIS only
- Look for low level cloud lines to extrapolate
- Look for overshooting top
- Look for SBC pattern in texture of CDO



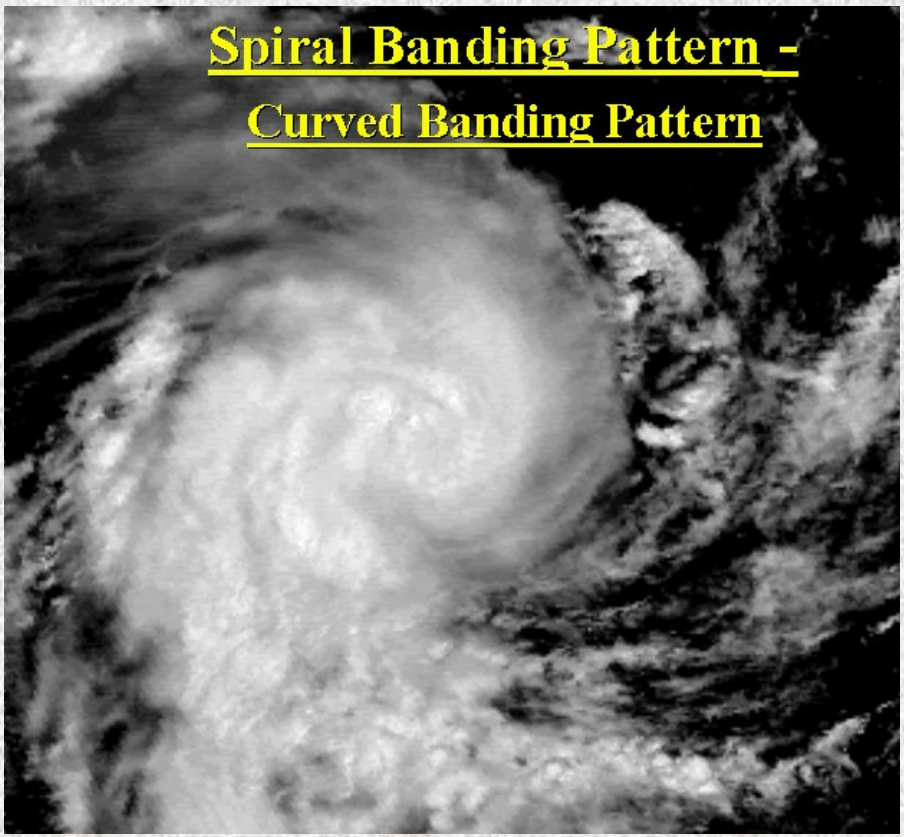
EMB CTR

- Look for a warm spot.
- Look toward the edge with the tightest temperature gradient.



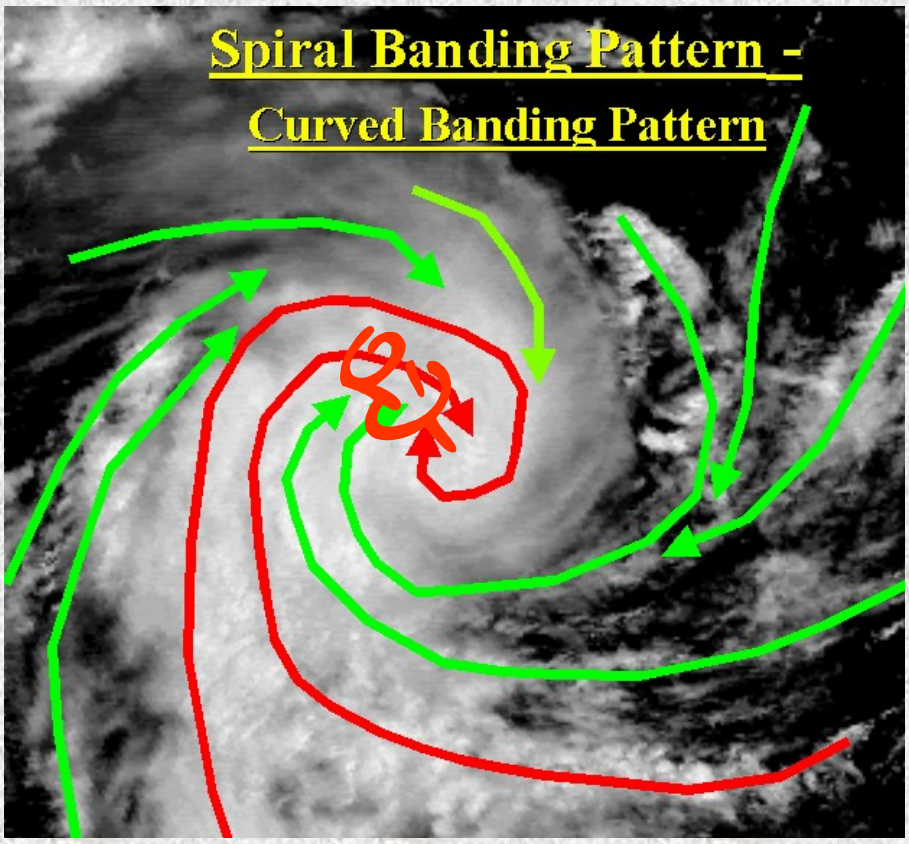
SBC Fixes VIS

- Draw Streamlines on the image.
- Place each streamline so the curve lies as close as possible to the low level cloud lines (LLCLS) and convective bands.
- Follow the curves to the center.



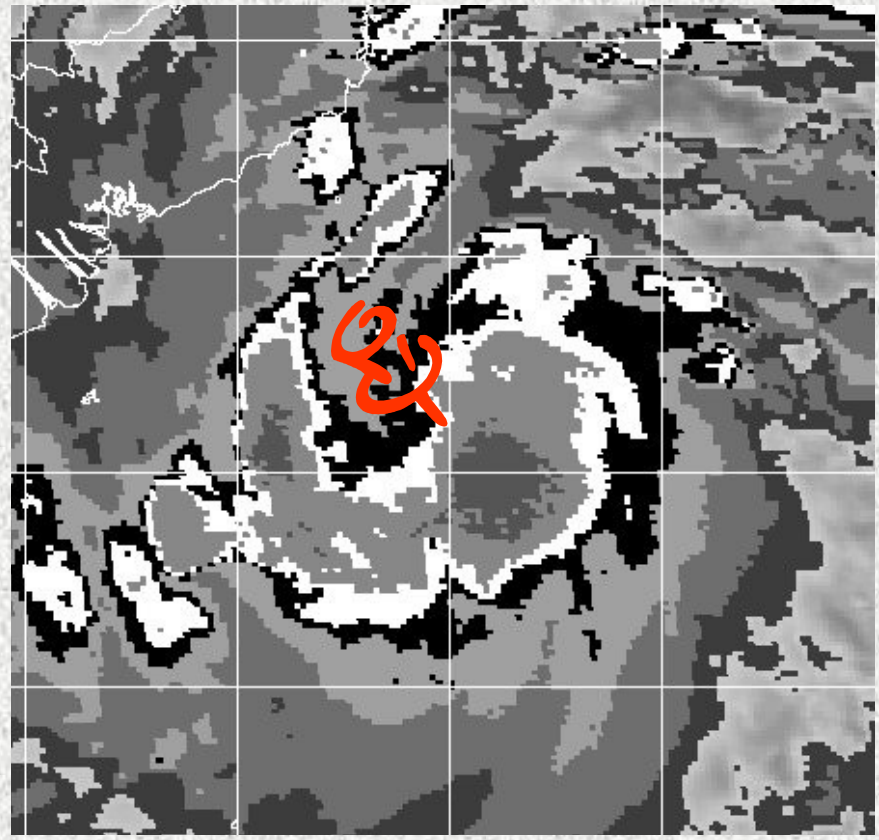
SBC Fixes VIS

- Draw Streamlines on the image.
- Place each streamline so the curve lies as close as possible to the low level cloud lines (LLCLS) and convective bands.
- Follow the curves to the center.

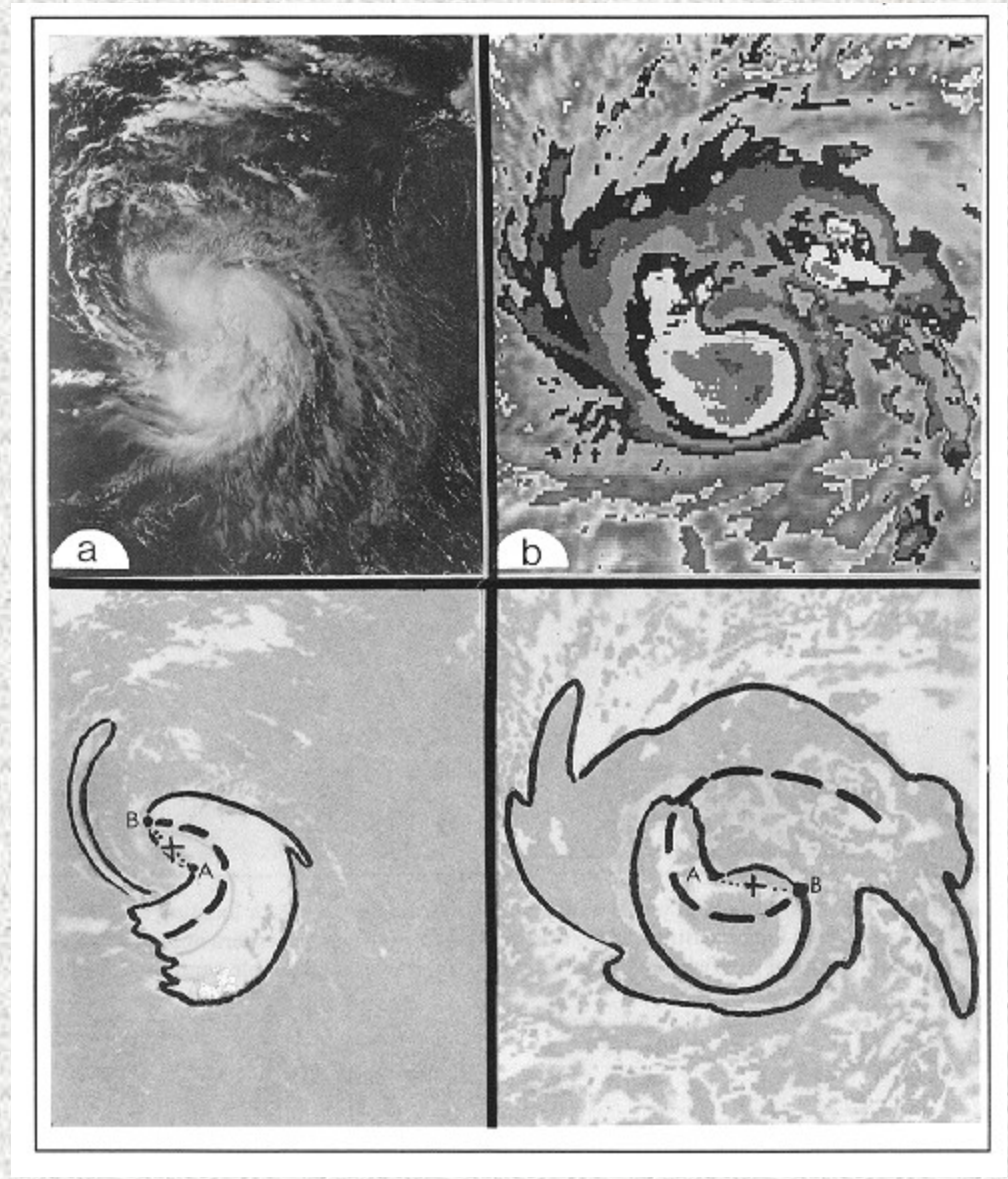


SBC Fixes IR

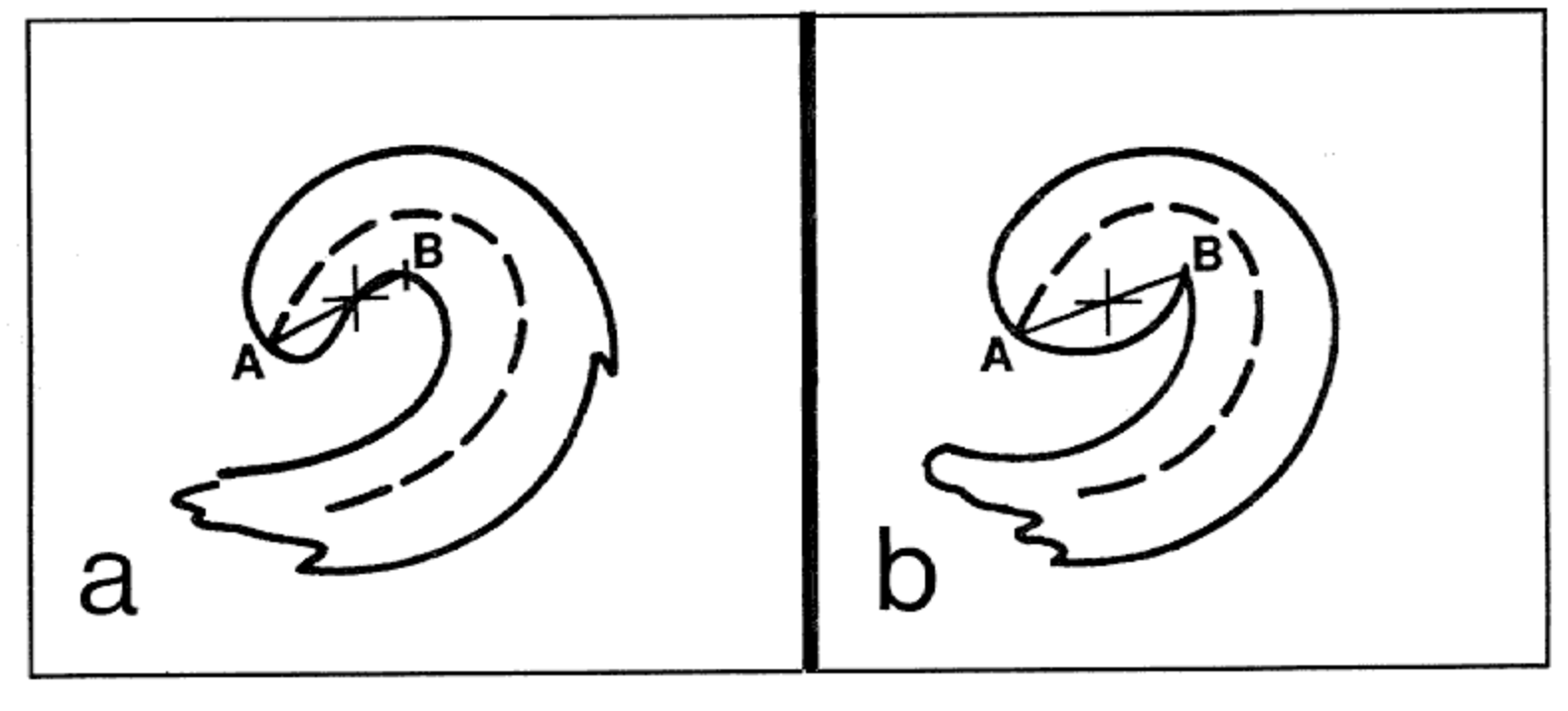
- Draw Streamlines on the image.
- Place each streamline so the curve lies as close as possible to the low level cloud lines (LLCLS) and convective bands.
- Follow the curves to the center
- Same idea as VIS



Curved Band Examples

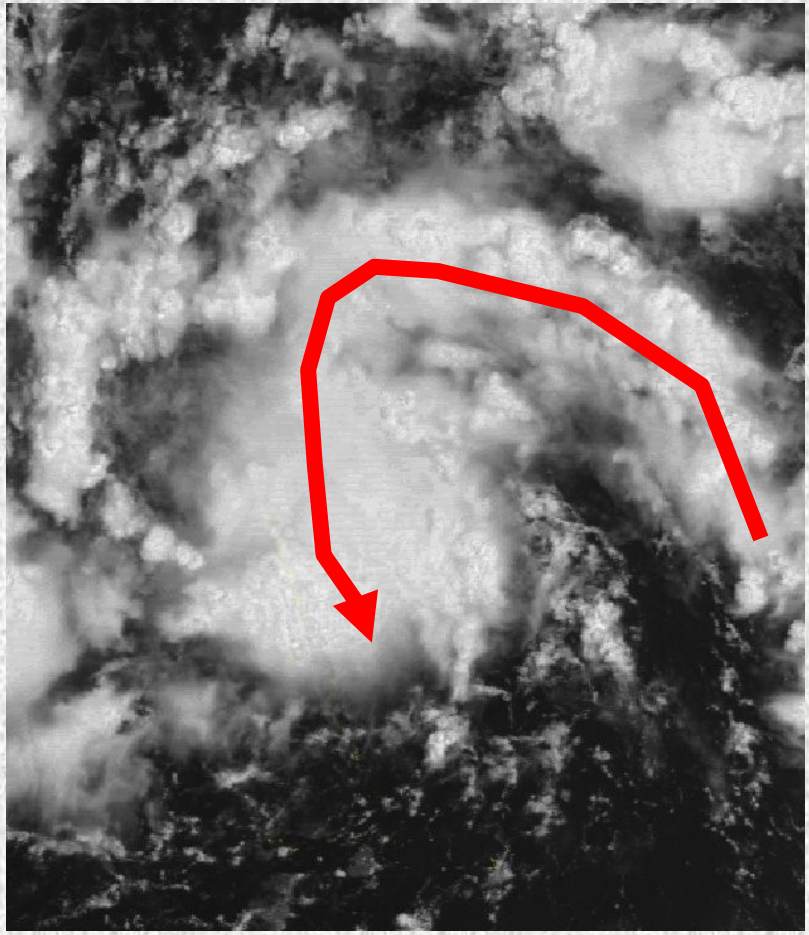


Expected CSC Positions for Curved Band Patterns



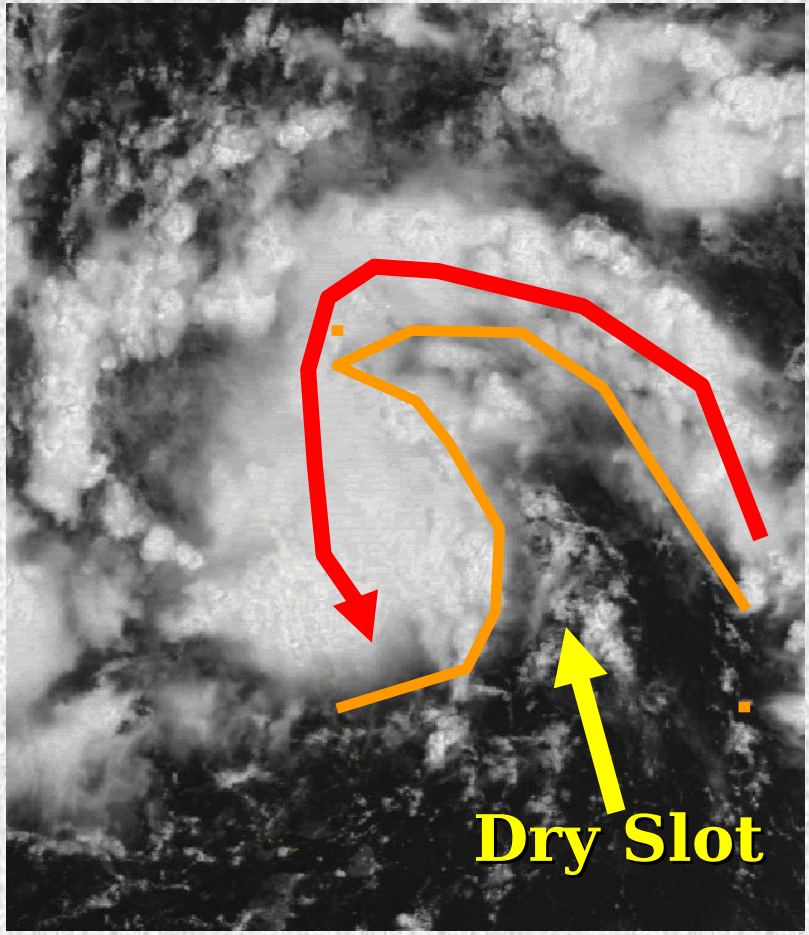
Cloud Minimum Wedge

- The center will be halfway along a line drawn from the tip of the wedge straight across the comma head.



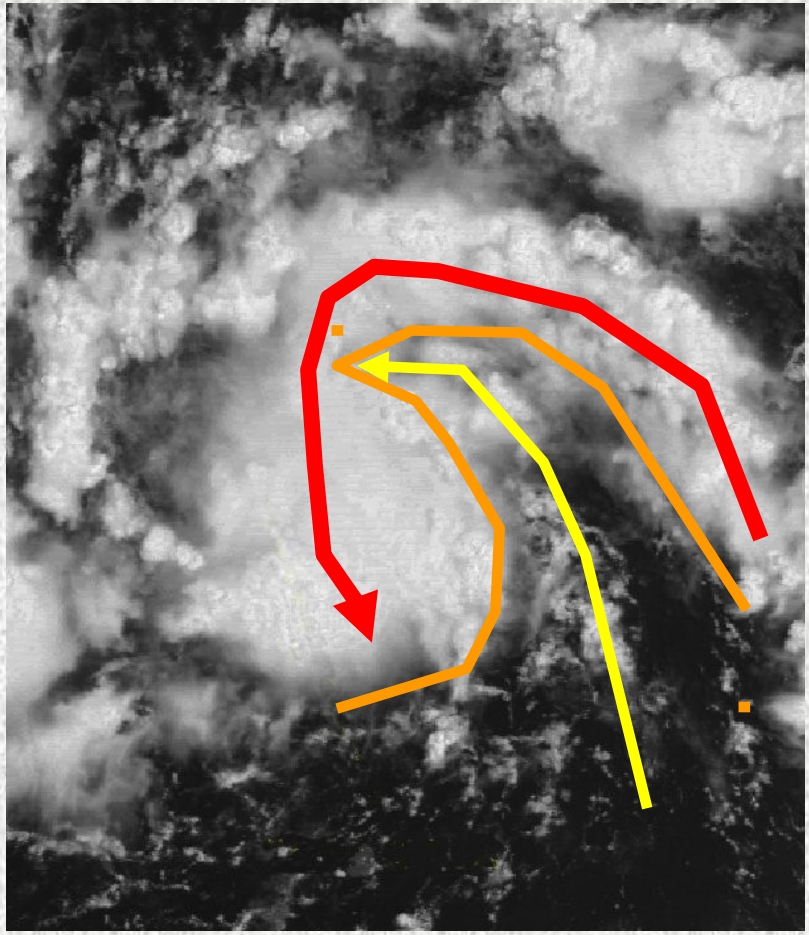
Cloud Minimum Wedge

- The center will be halfway along a line drawn from the tip of the wedge straight across the comma head.



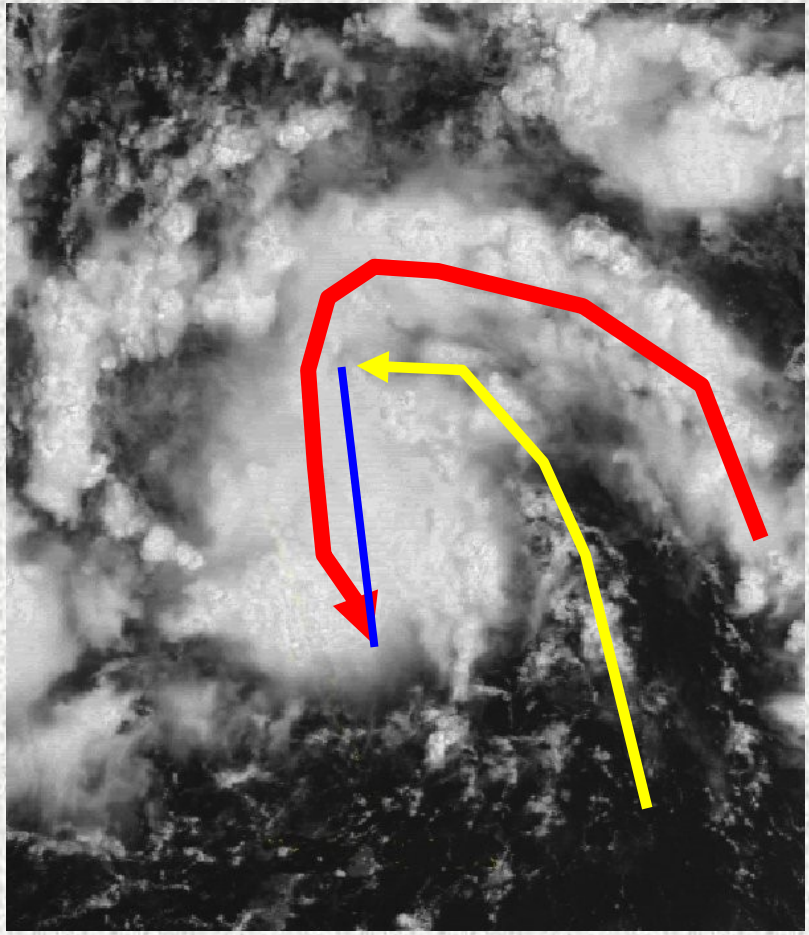
Cloud Minimum Wedge

- The center will be halfway along a line drawn from the tip of the wedge straight across the comma head.



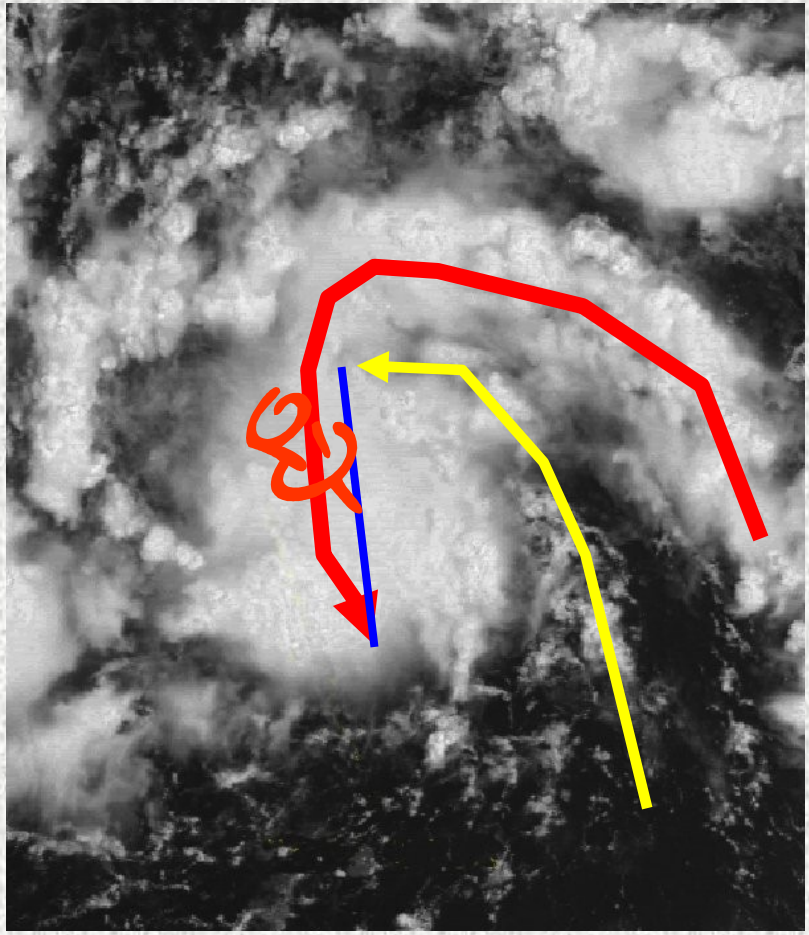
Cloud Minimum Wedge

- The center will be halfway along a line drawn from the tip of the wedge straight across the comma head.



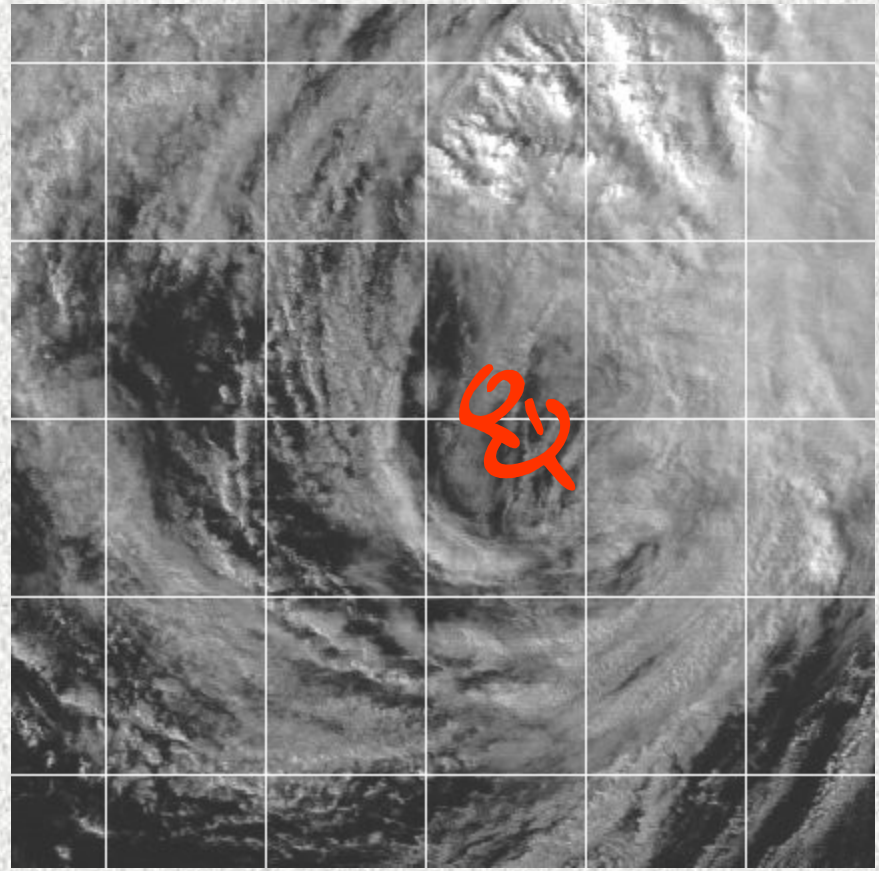
Cloud Minimum Wedge

- The center will be halfway along a line drawn from the tip of the wedge straight across the comma head.



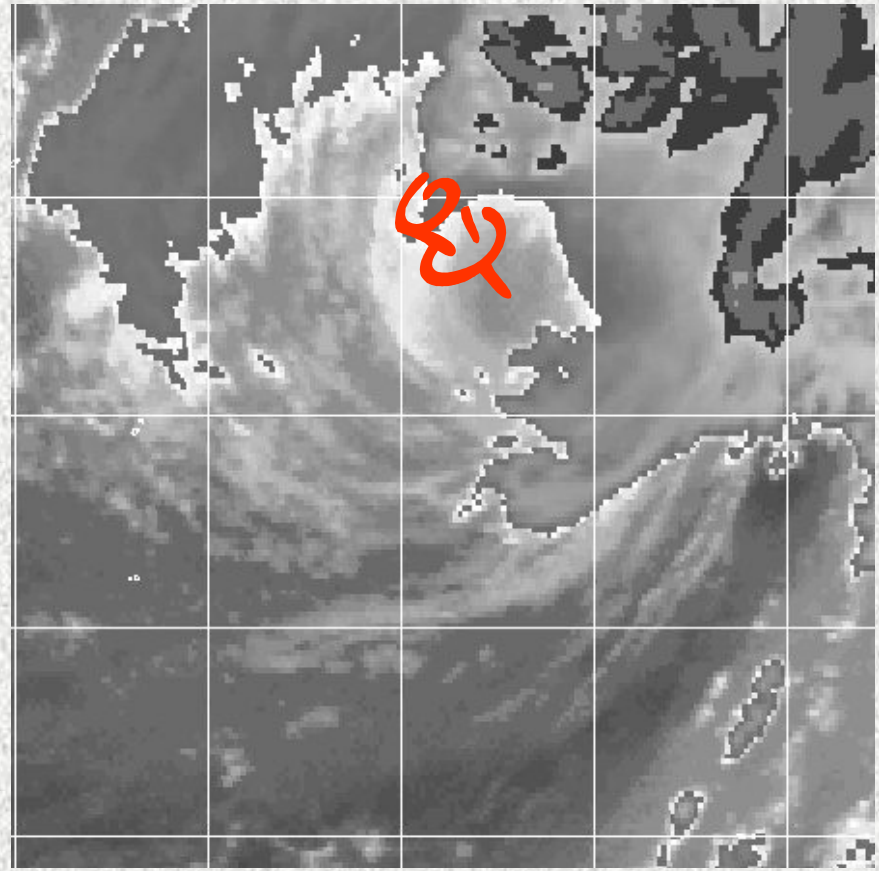
Partially Exposed LLCC Fixes VIS

- Less than half of the LLCC exposed



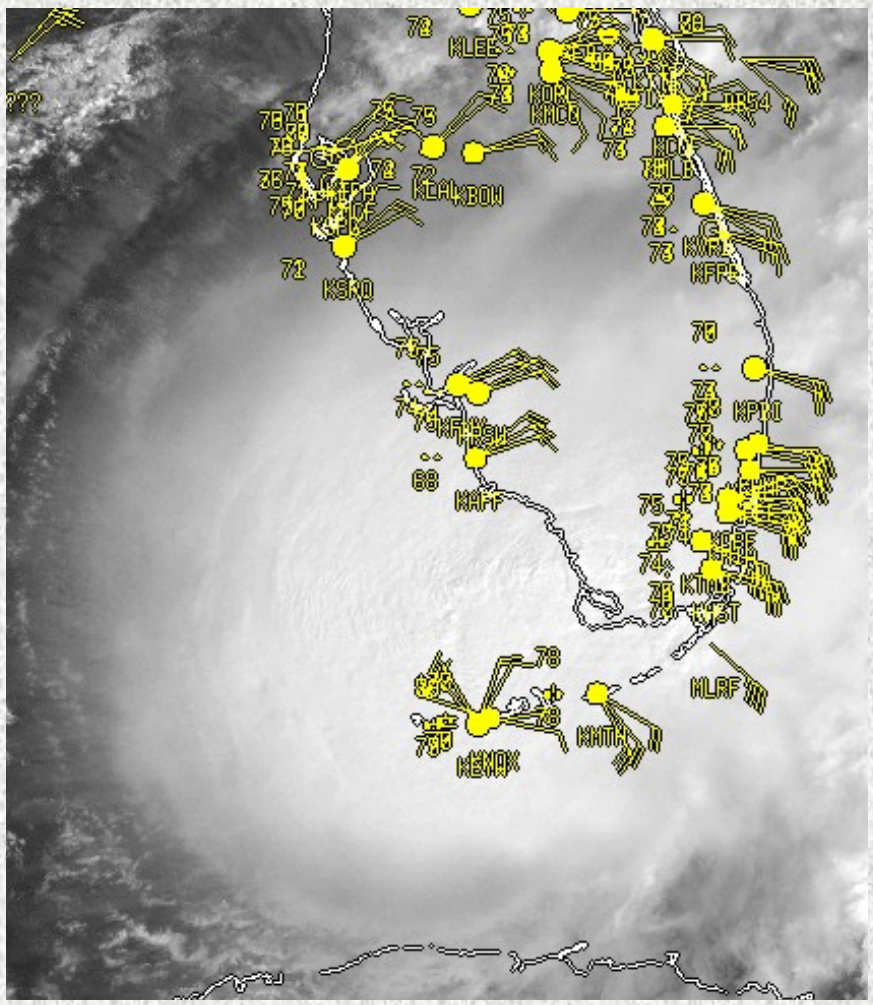
Partially Exposed LLCC Fixes IR

- Less than half of the LLCC exposed



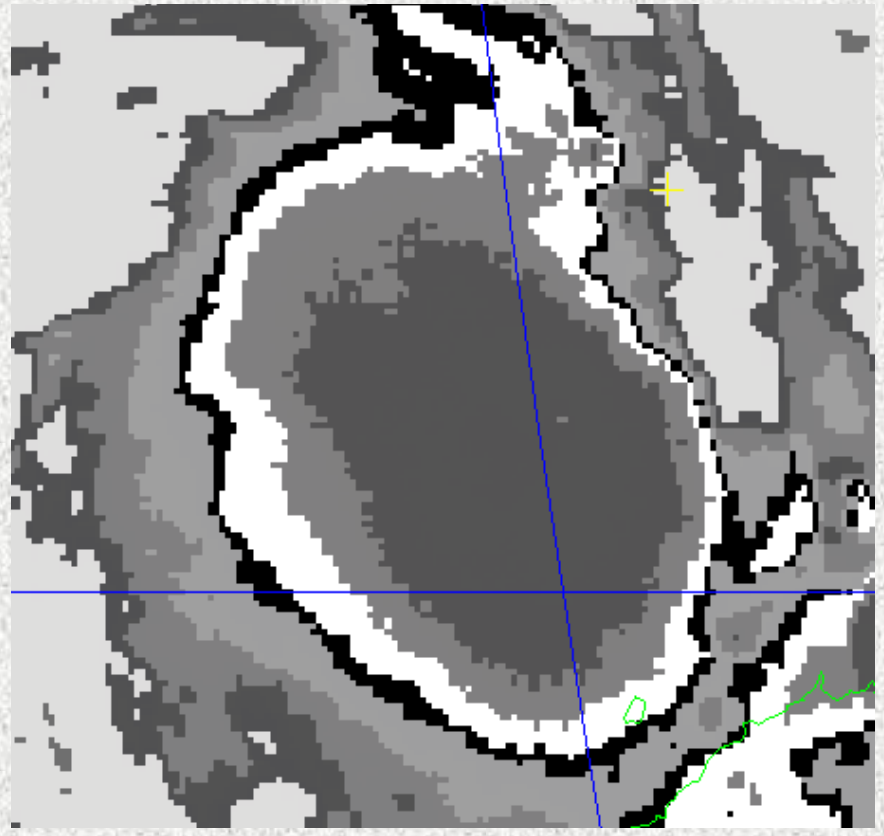
Central Cold Cover (CCC) Fixes VIS

- Rare to be used with VIS imagery.
- Only use if there is no evidence of the CDO or curved lines visible through the cirrus.
- Center placement based mostly on continuity.



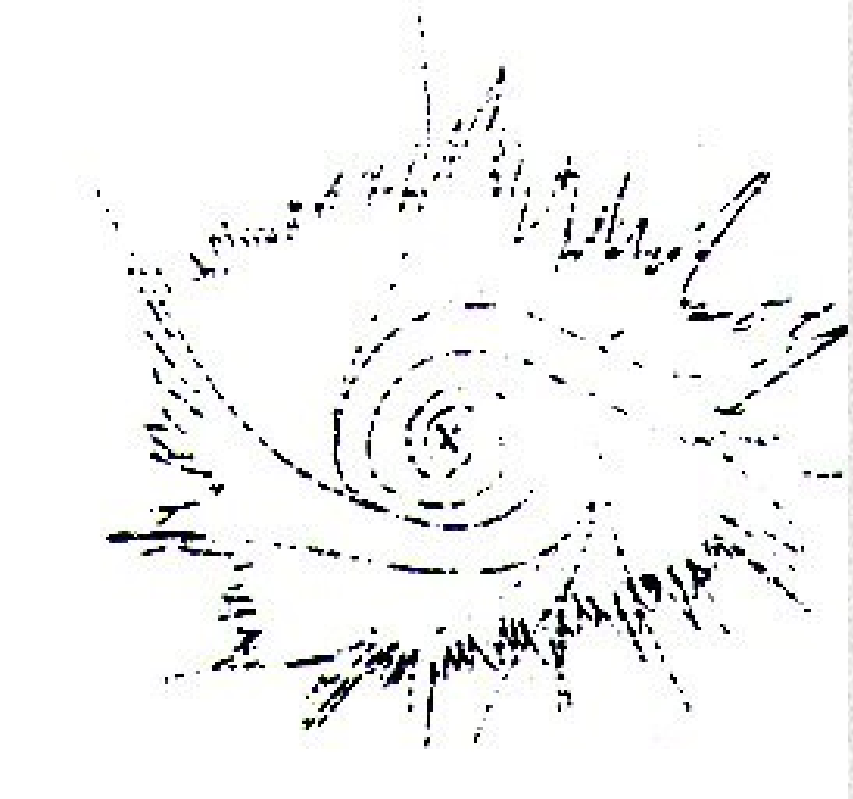
CCC Fixes IR

- Very difficult to accurately locate center.
- Center placement based mostly on continuity.



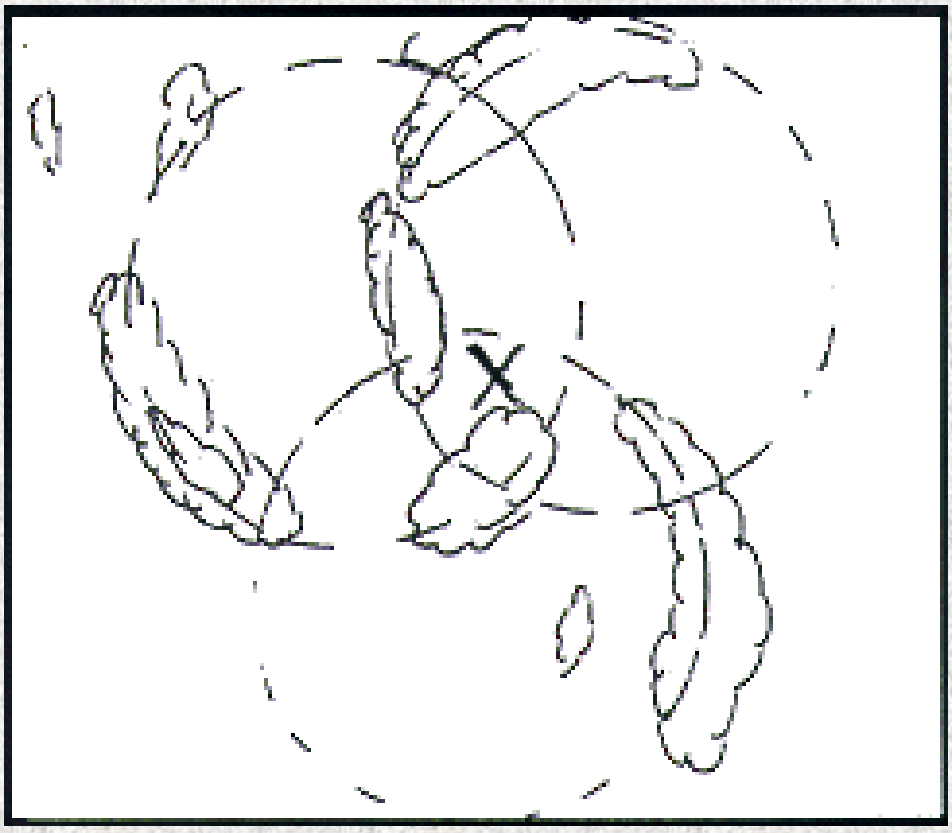
Cirrus Outflow Fixes

- Use only when low clouds are not visible.
- Follow the cirrus outflow anticyclonically back to the center.
- This locates the Upper Level Circulation Center (ULCC)
- Scat data can greatly assist



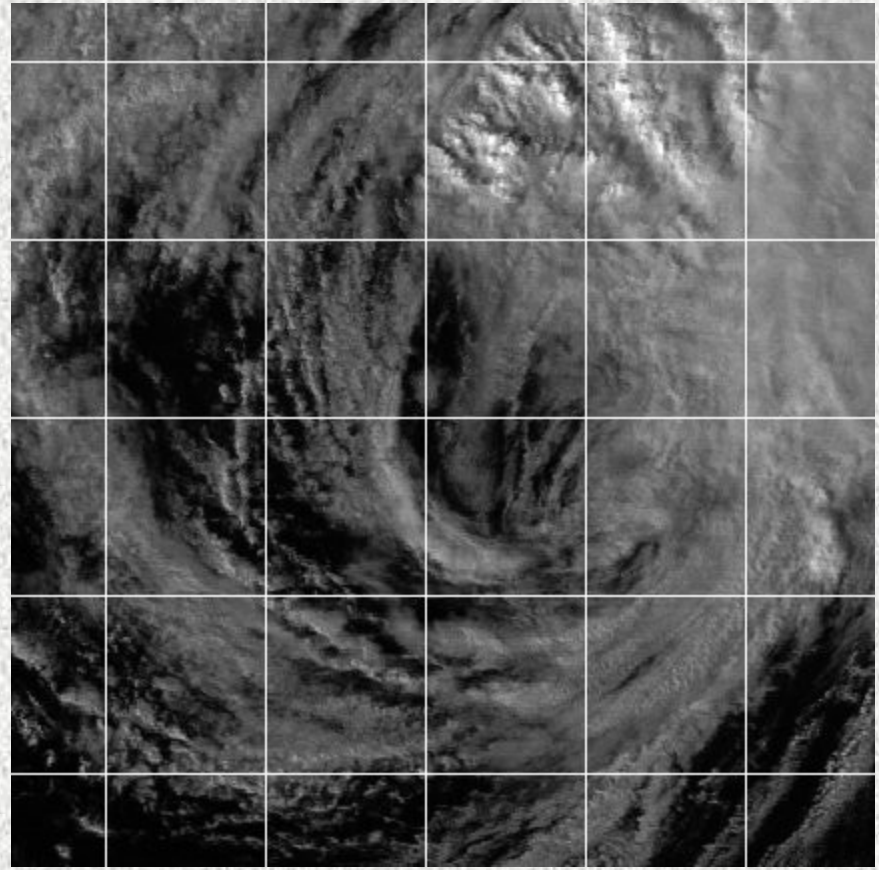
Circle Method Fixes

- To be used with weak or very broad systems.
- Use all available curvature to find center.
- Where most circles meet, indicates most likely LLCC.



Conservative Features Fixes

- If you had good reason to believe the LLCC was located at a certain point in relationship with a persistent feature, the LLCC will remain in the same relative location for up to 12 hours (at the very furthest in time).

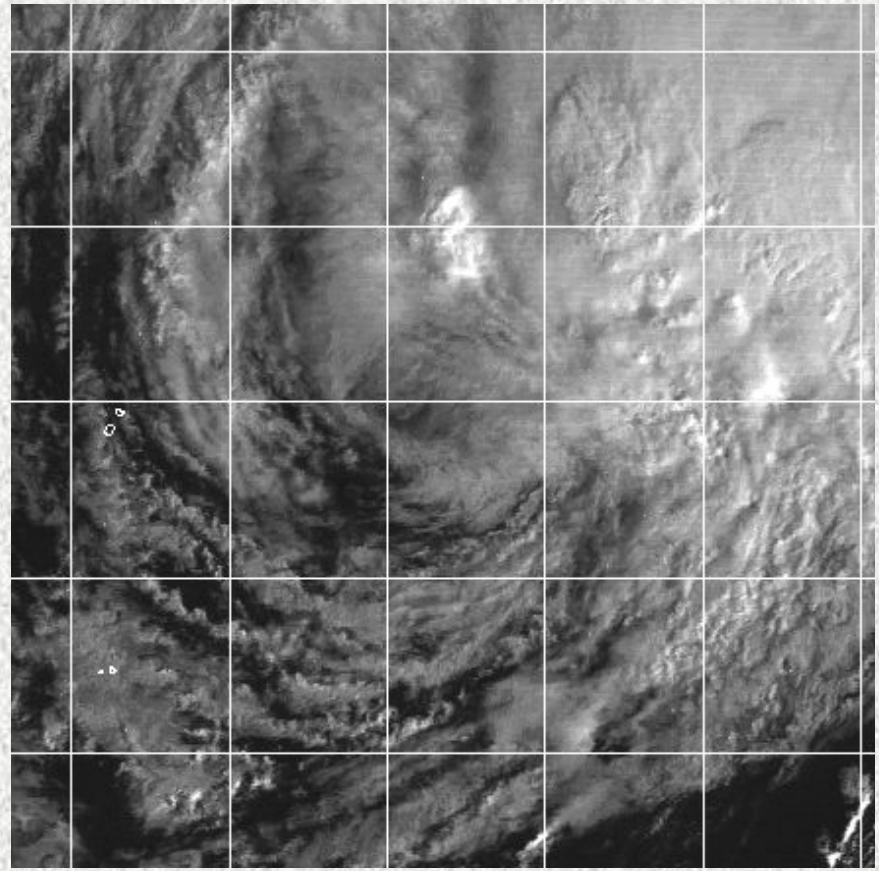


Animation Fixes

- Use with all type of fixes when available.
- Use alone only when still imagery gives no indication of LLCC.

Extrapolation Fixes

- Extrapolate past few fixes to predict where current position will be.
  - Limited by the accuracy of the past fixes



Intensity Estimation

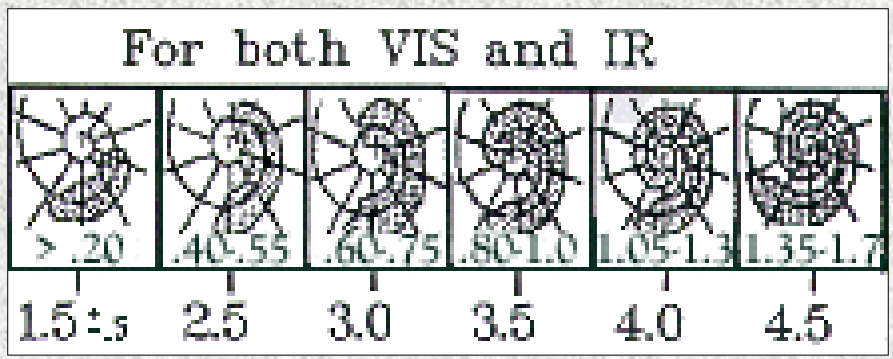
- Step 1 - Locate Cloud System Center (CSC)
- Step 2 - Determine the Data Type (Data-T)
- Step 3 - CCC
- Step 4 - Past 24 hour trend
- Step 5 - Model Expected T-number (MET)
- Step 6 - Pattern T-number (PT)
- Step 7 - T-number determination
- Step 8 - Final-T
- Step 9 - Current Intensity (CI)
- Step 10 - Final-T/CI encoding

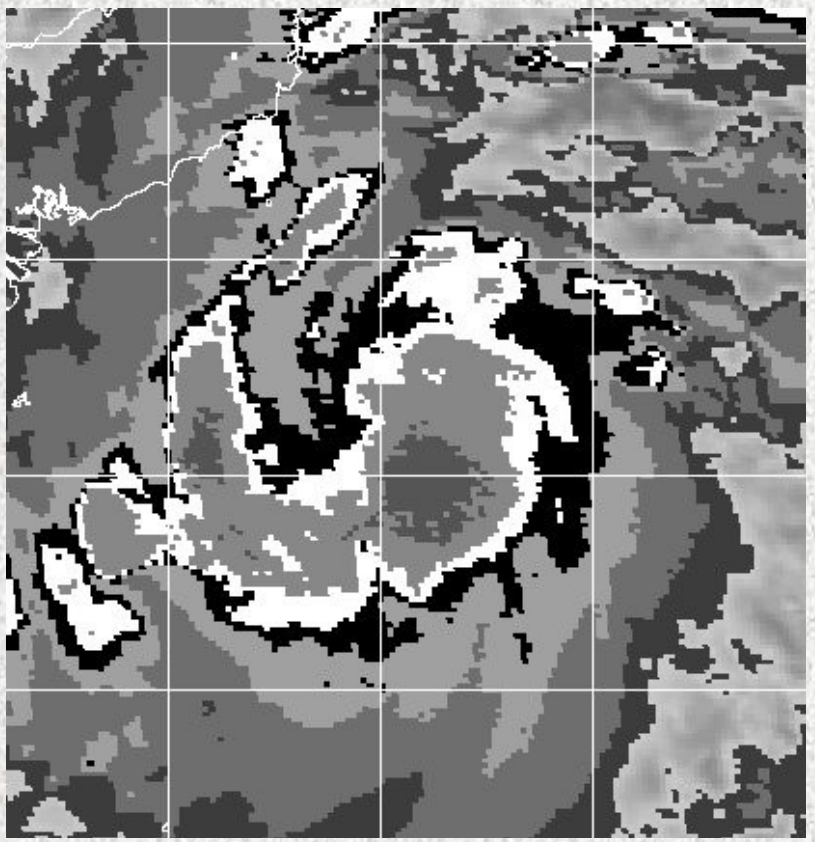
Step 2, Data-T

- Step 2A Curved Band
- Step 2B Shear Pattern
- Step 2C Eye Pattern
- Step 2D CDO
- Step 2E Embedded Center

Step 2A, Curved Band

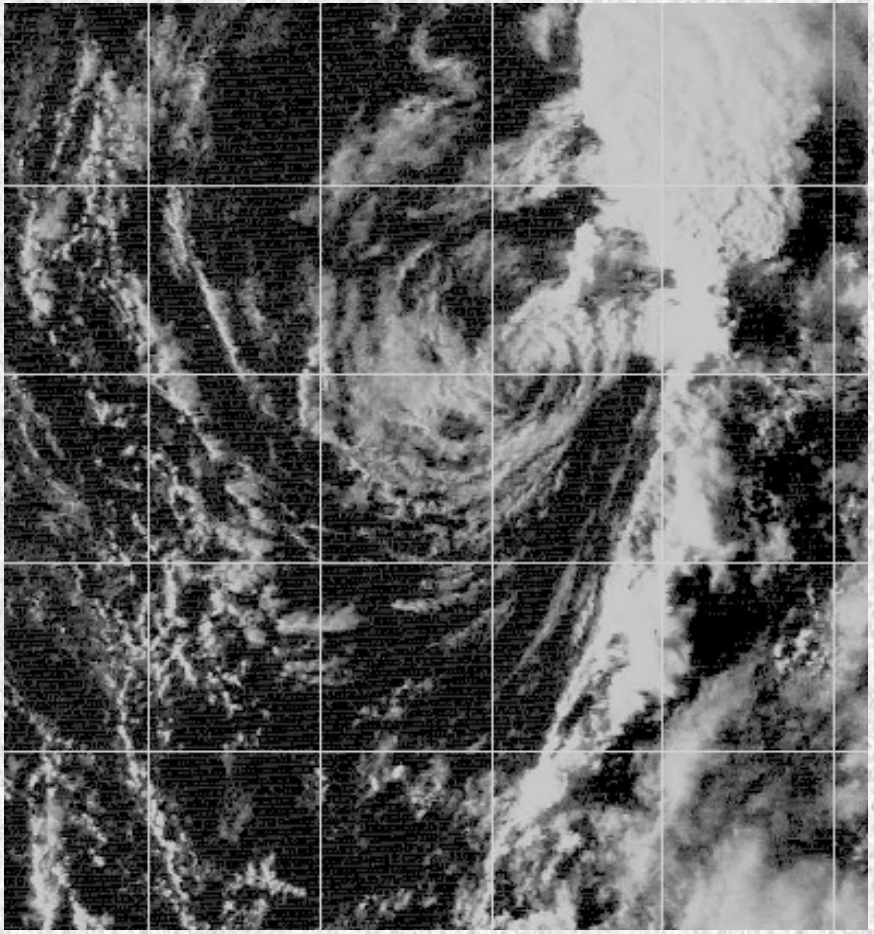
- Use a LOG10 spiral overlay.
- The spiral should lie along the axis of the of the band, and roughly parallel the inside edge of the band.
- Measure the arc length.



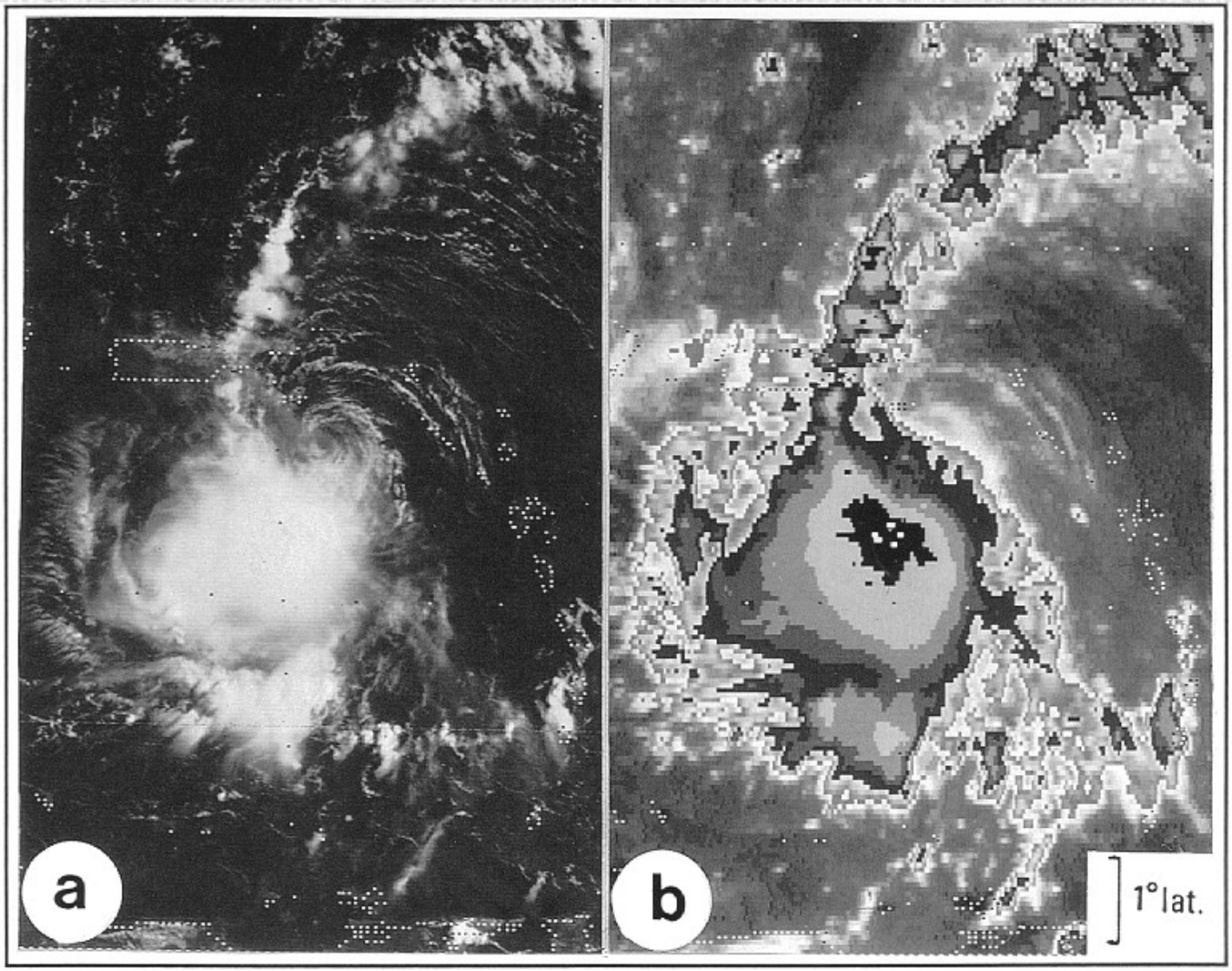


Step 2B, Shear Pattern

- Measure the distance from the LLCC to the nearest convection.
- In IR, use the dark gray shade to identify convection.



Shear Example



Sheared Systems

- The shear pattern is only used to define systems less than typhoon strength.

- Systems may be divided into two categories: pre-storm, and tropical storm strength.

Sheared Systems

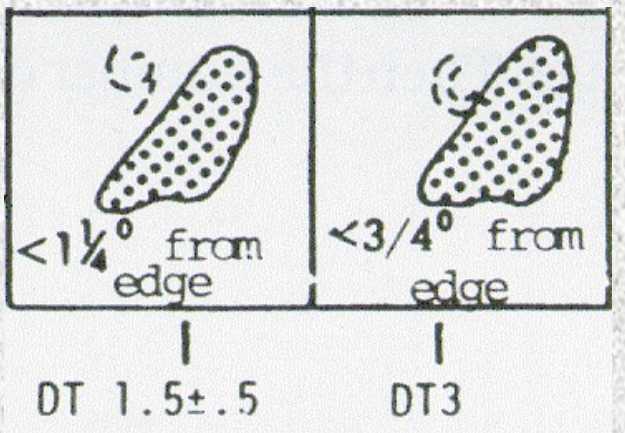
To Analyze the pattern, two factors must be considered:

1) The appearance of the low cloud lines that define the center

2) The distance between the center and the dense overcast clouds of the pattern

Sheared Systems

This is a chart we use for classification:



Unfortunately, it only accounts for one part of the equation … the distance

Sheared Systems

The **First** step is to determine the characteristics of the Low Level Circulation Center (LLCC)

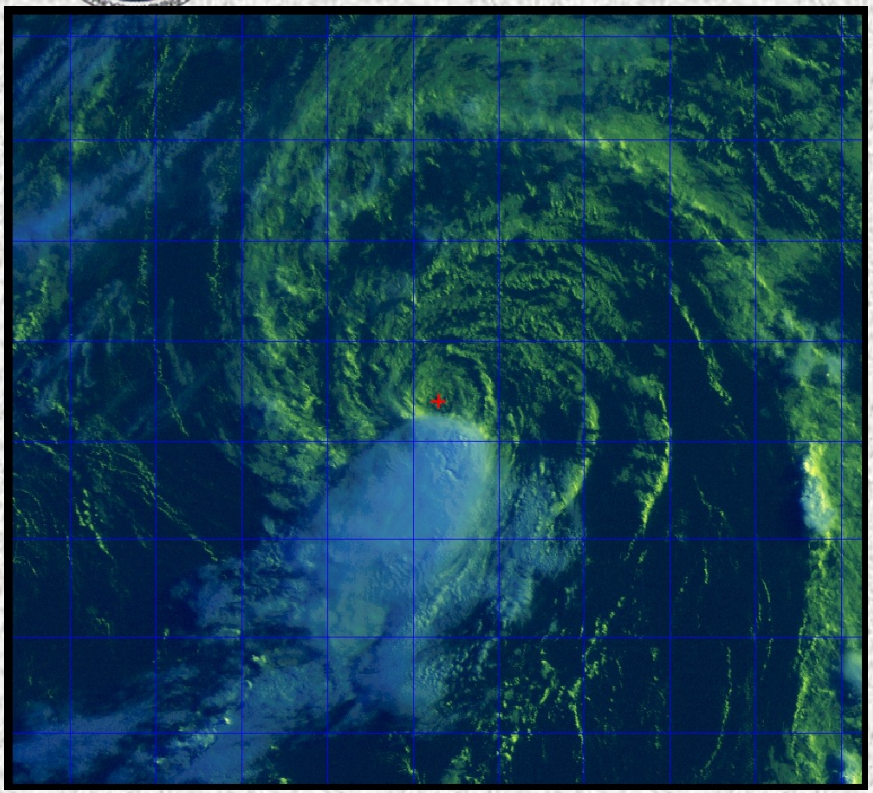
Is it defined by:

- parallel low level cloud lines?(T3.0 $\pm$.5)

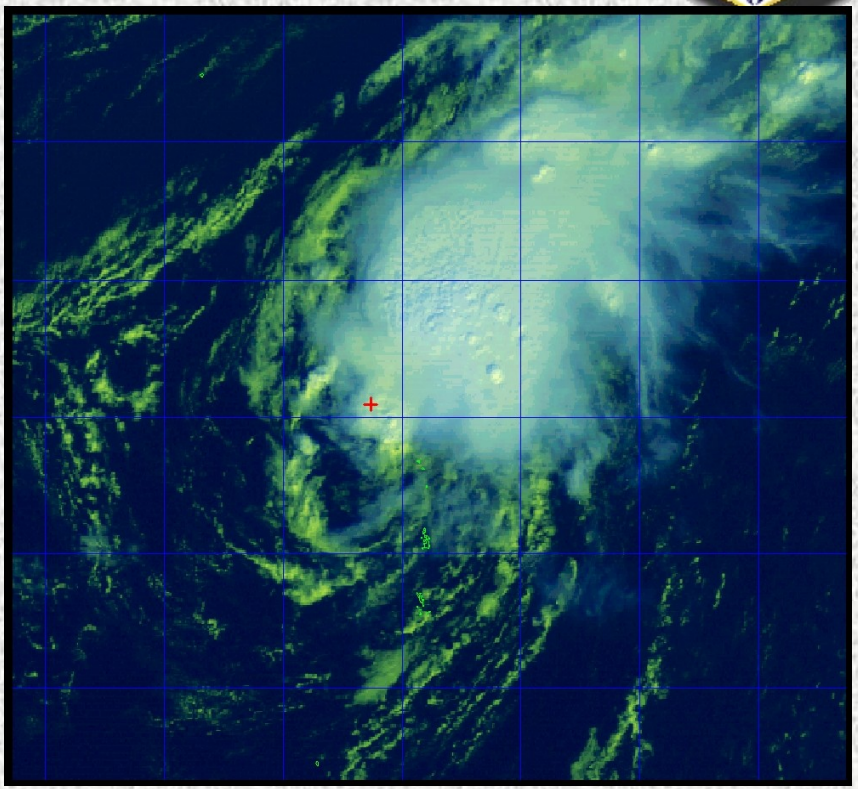
or …

- low level cloud lines that are weak and not

Sheared Systems



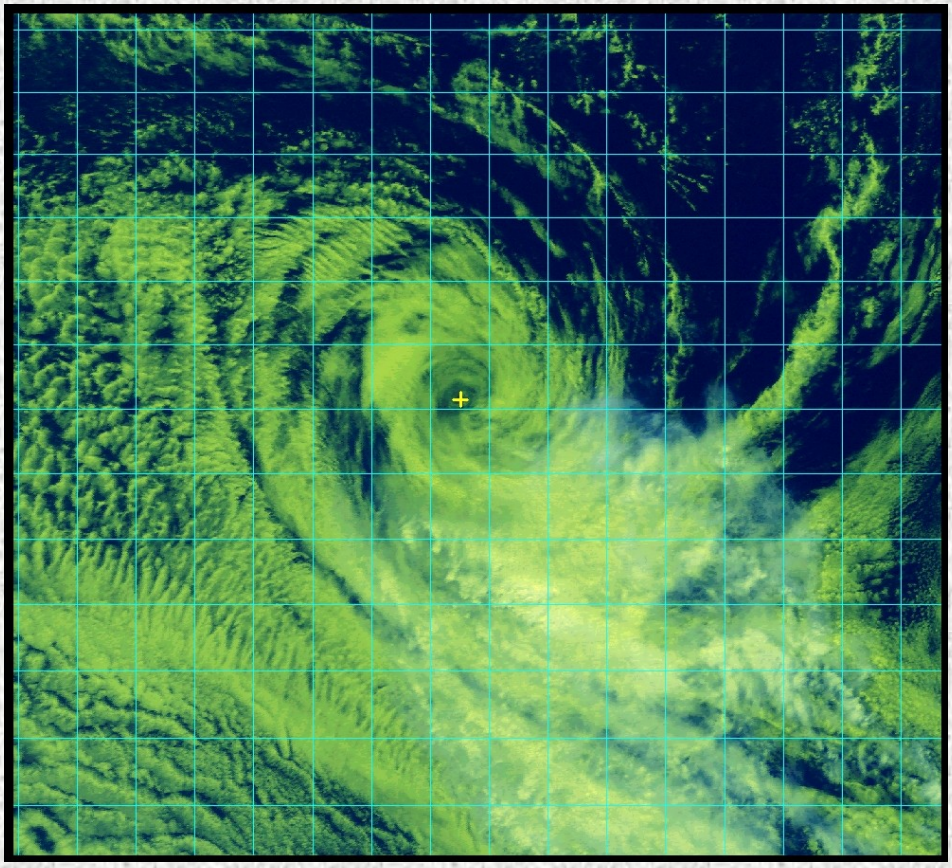
T3.0±.5 well defined parallel cloud lines



T1.5±.5 weak poorly defined non-parallel cloud lines

Both systems are within 3/4 degrees of the dense overcast convection

Sheared Systems



T1.5±.5 well defined parallel
cloud lines >3/4 from deep convection

Although DT/FT will be below TS strength, it's likely that in many cases the CI will still indicate TS strength

Step 2C, Eye Pattern

- Terms
  - E#: Eye Number
  - Eye adj: Eye adjustment
  - CF: Central Feature
  - BF: Banding Feature
- CF Formula: CF = E# + Eye adj
- Data-T Formula: DT = CF + BF

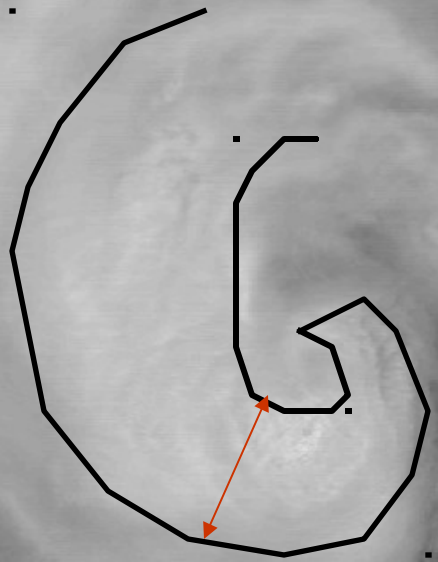
Step 2C (E# VIS)

- Determine if Eye is banding type or not.
- Measure the embedded distance of the eye, or the average band width if eye is a banding type.
- For small eyes, measure distance from center.
- For large eyes (≥ 30 nm) measure from edge.
- Apply Values to E# Table

E# for Visual

Embedded Distance	>1° 60nm	=1° 60nm	=¾° 45nm	=½° 30nm	=¼° 15nm	Banding Eyes		
Average Band Width						1¼° 75nm	¾° 45nm	¼° 15nm
E#	7	6	5	4	3	5	4	3

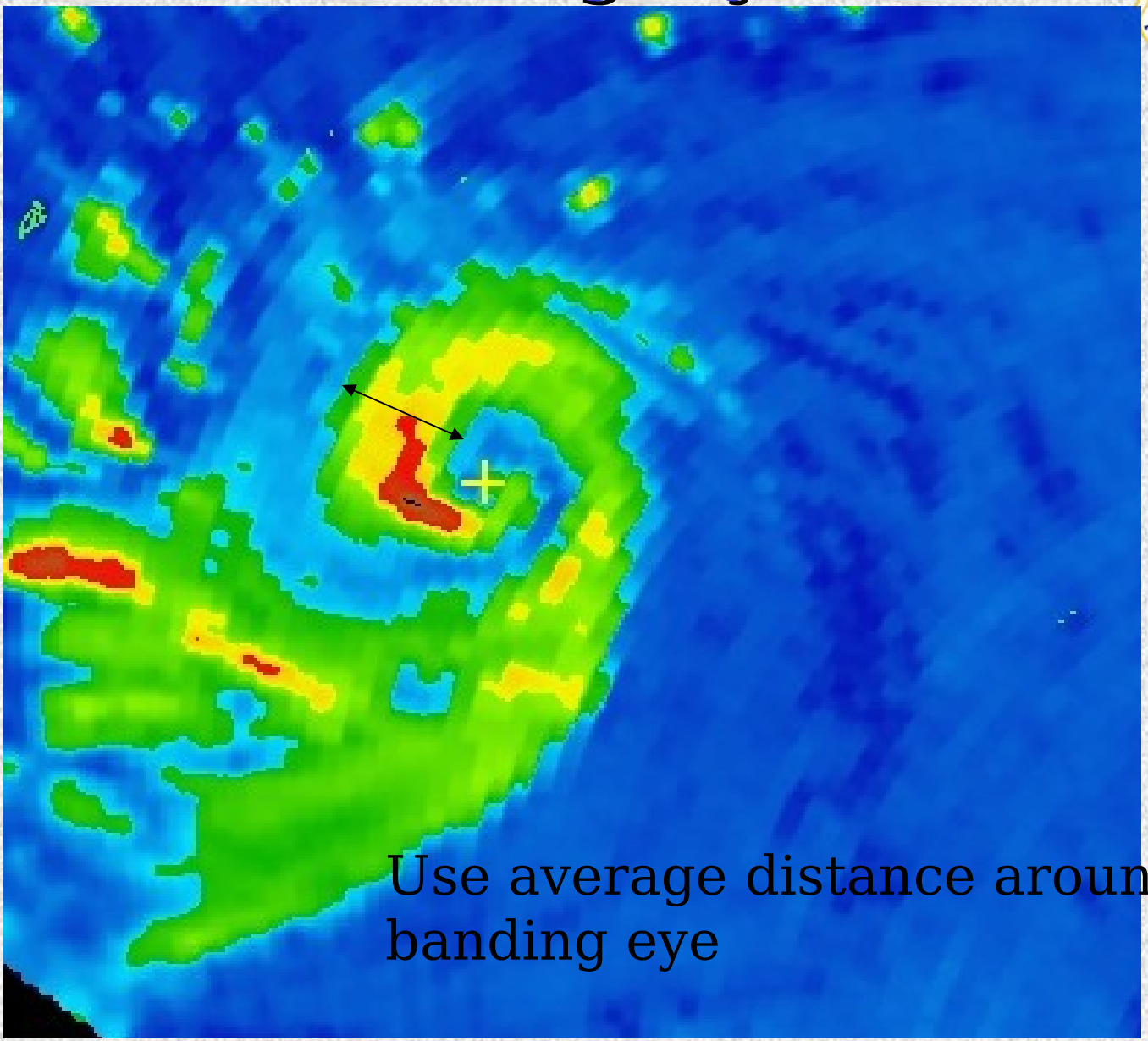
Banding Eye



E# for Visual

Embedded Distance	>1° 60nm	=1° 60nm	=¾° 45nm	=½° 30nm	=¼° 15nm	Banding Eyes		
Average Band Width						1¼° 75nm	¾° 45nm	¼° 15nm
E#	7	6	5	4	3	5	4	3

Banding Eye

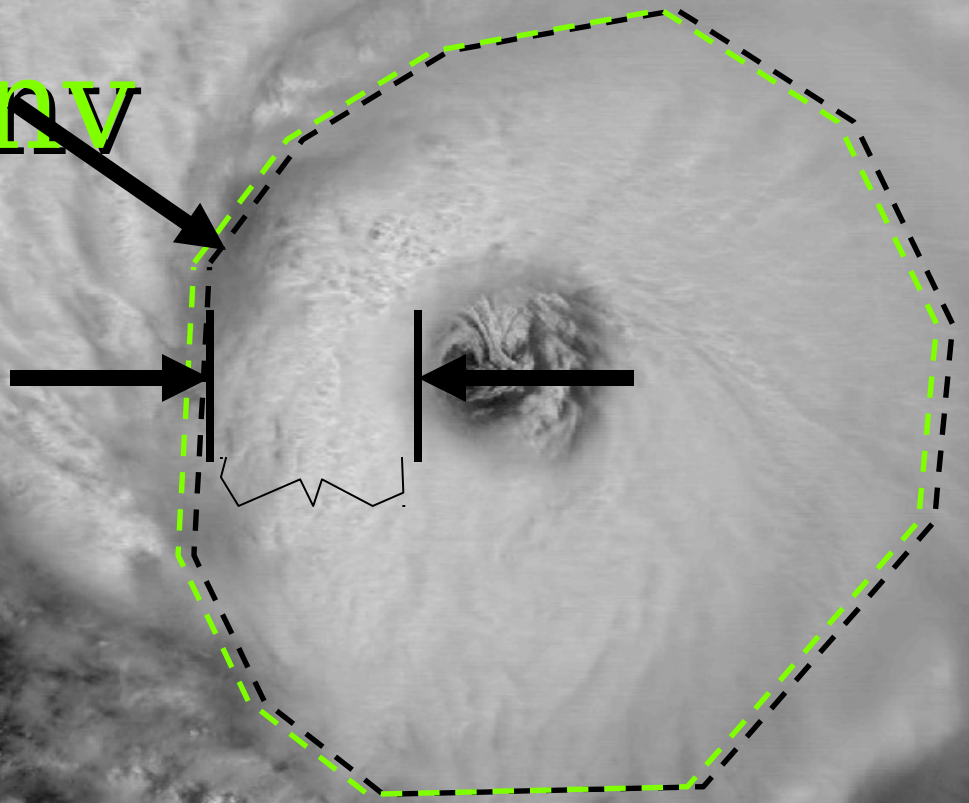


Use average distance around the banding eye

Eye Measurement

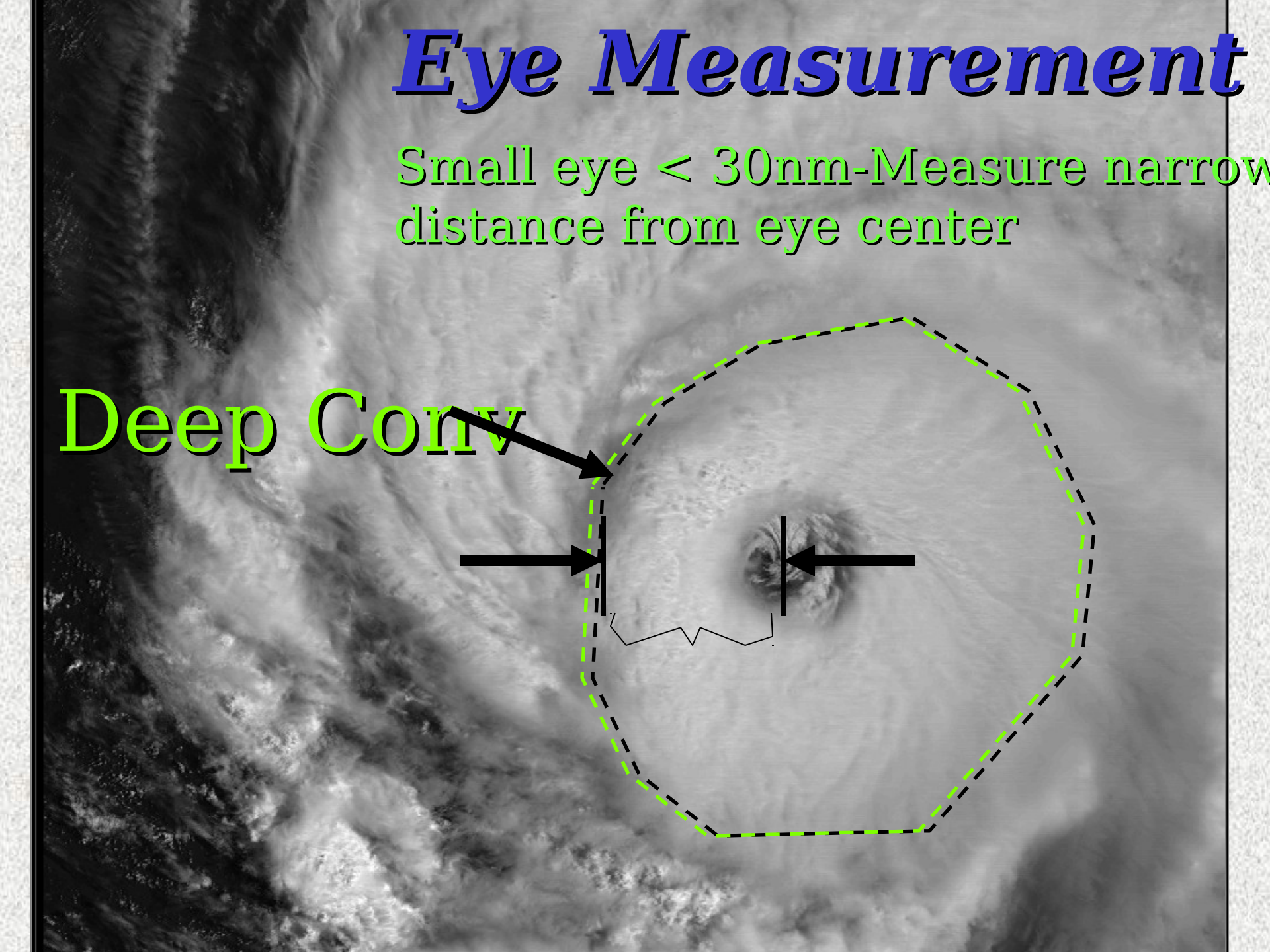
Large eye ≥ 30nm-Measure narrow
distance from outer edge of eye

Deep Conv



Eye Measurement

Small eye < 30nm-Measure narrow
distance from eye center

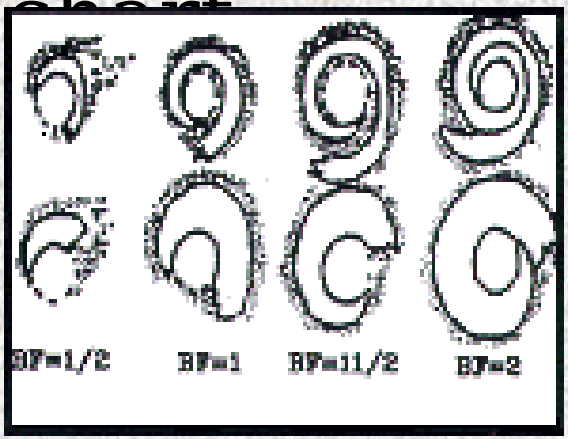


Step 2C (Eye adj VIS)

- For poorly defined or ragged eyes subtract .5 if E# $\leq$ 4.5, and subtract 1.0 if E# > 4.5.
- Add .5 or 1.0 if the eye is well defined, circular, and embedded in a smooth, very dense canopy
- Add .5 or whole 1.0, IF the MET $\geq$ 6.0, & the CF is less than the MET.

Step 2C (BF VIS)

- Dense, mostly overcast band that curves at least 1/4 distance around the central feature.
- Rarely used if CF is greater than 4.0.
- Compare to chart



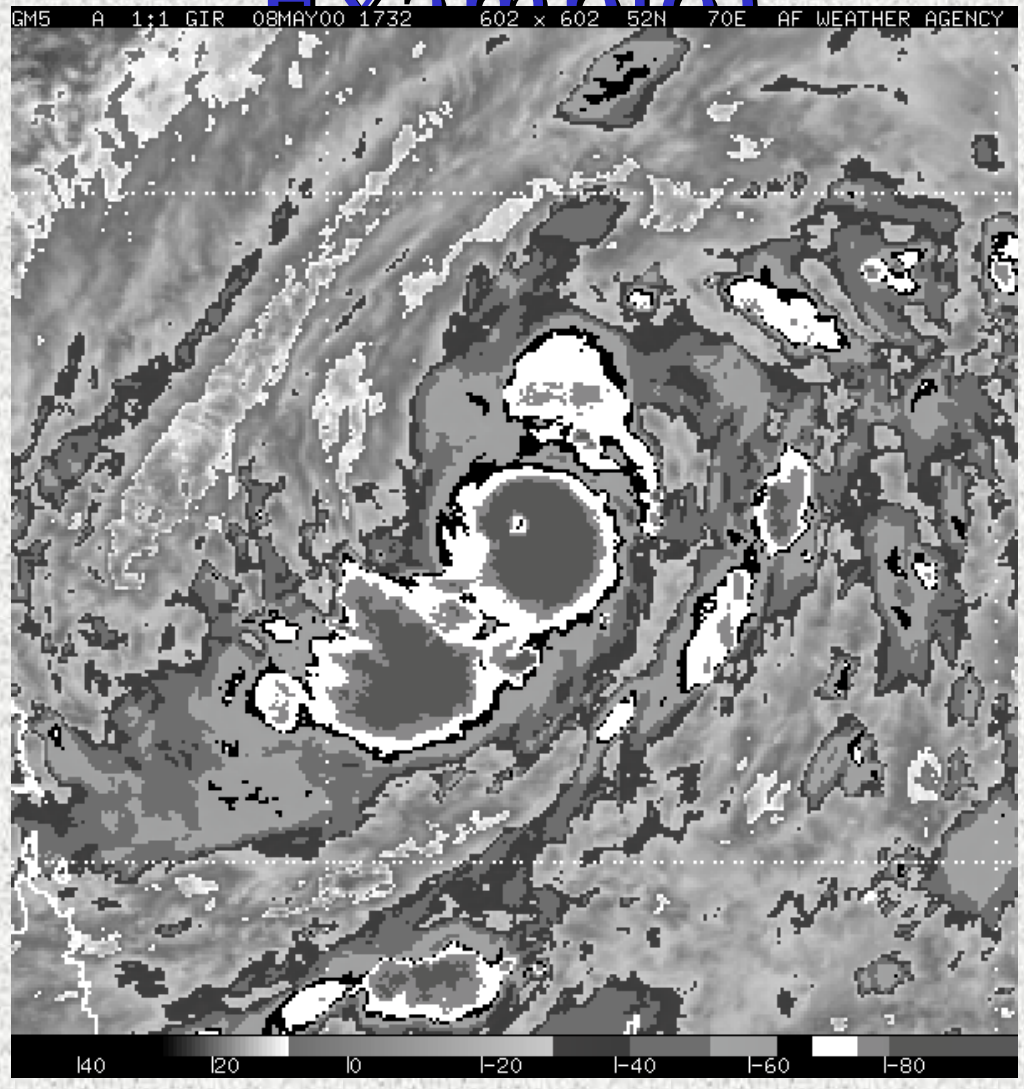
Step 2C (E# IR)

- Find the shade of the coldest ring completely surrounding the eye.
- Measure the distance from the edge of the eye to the outside edge of the coldest surrounding ring.
- For EIR, DO NOT USE center of eye ever (center is only used in VISUAL)!
- Apply Values to E# Table

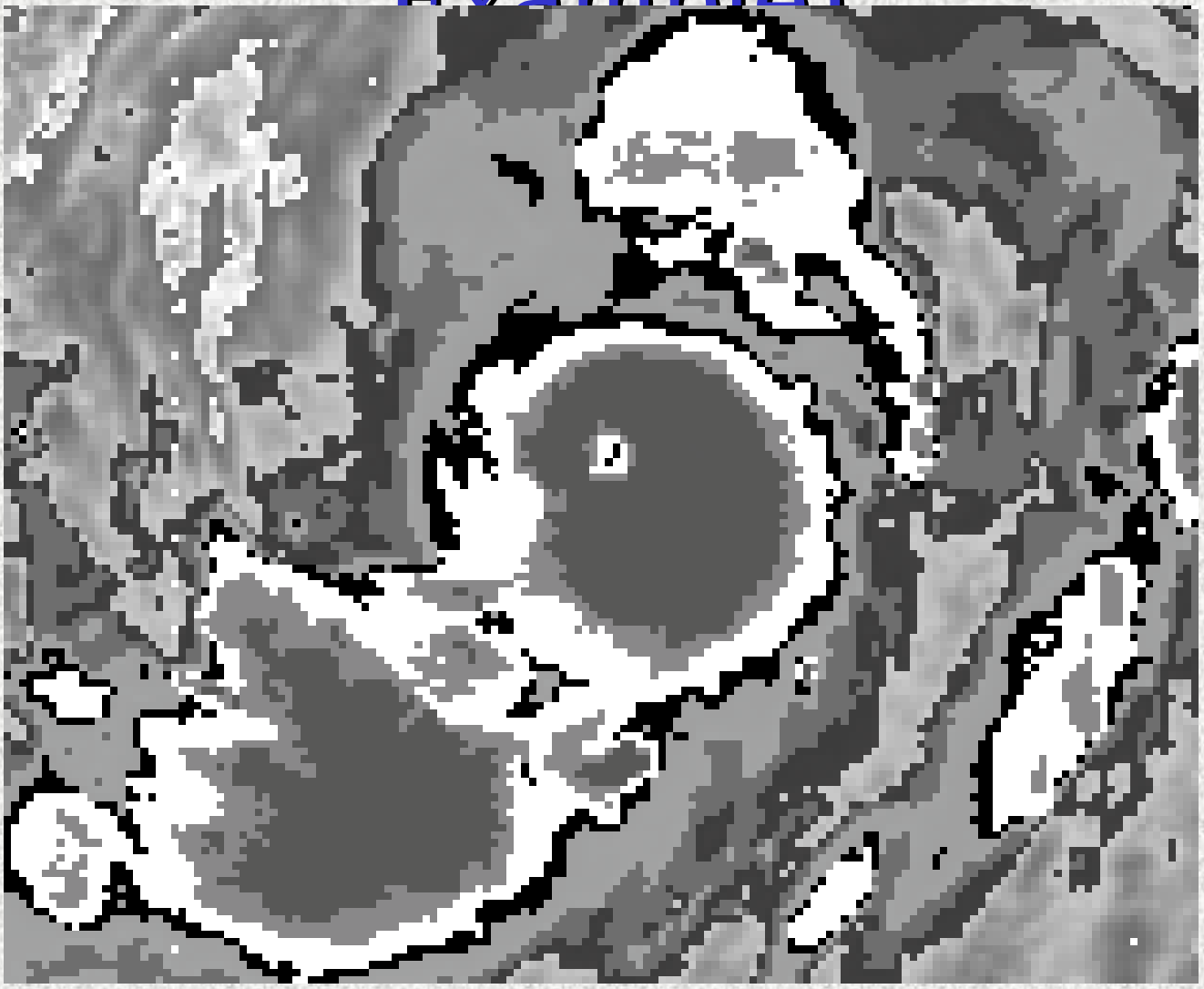
E# Table for Enhanced IR

Narrowest Width	≥2.5° 30nm	≥2.5° 30nm	≥2.5° 30nm	≥2.4° 24nm	≥2.4° 24nm	≥2.3° 18nm	≥2.3° 18nm
Surround Gray Shade	CMG	W	B	LG	MG	DG	OW
E#	6.5	6	5.5	5	4.5	4.5	4

Step 2C (E# IR, Example)



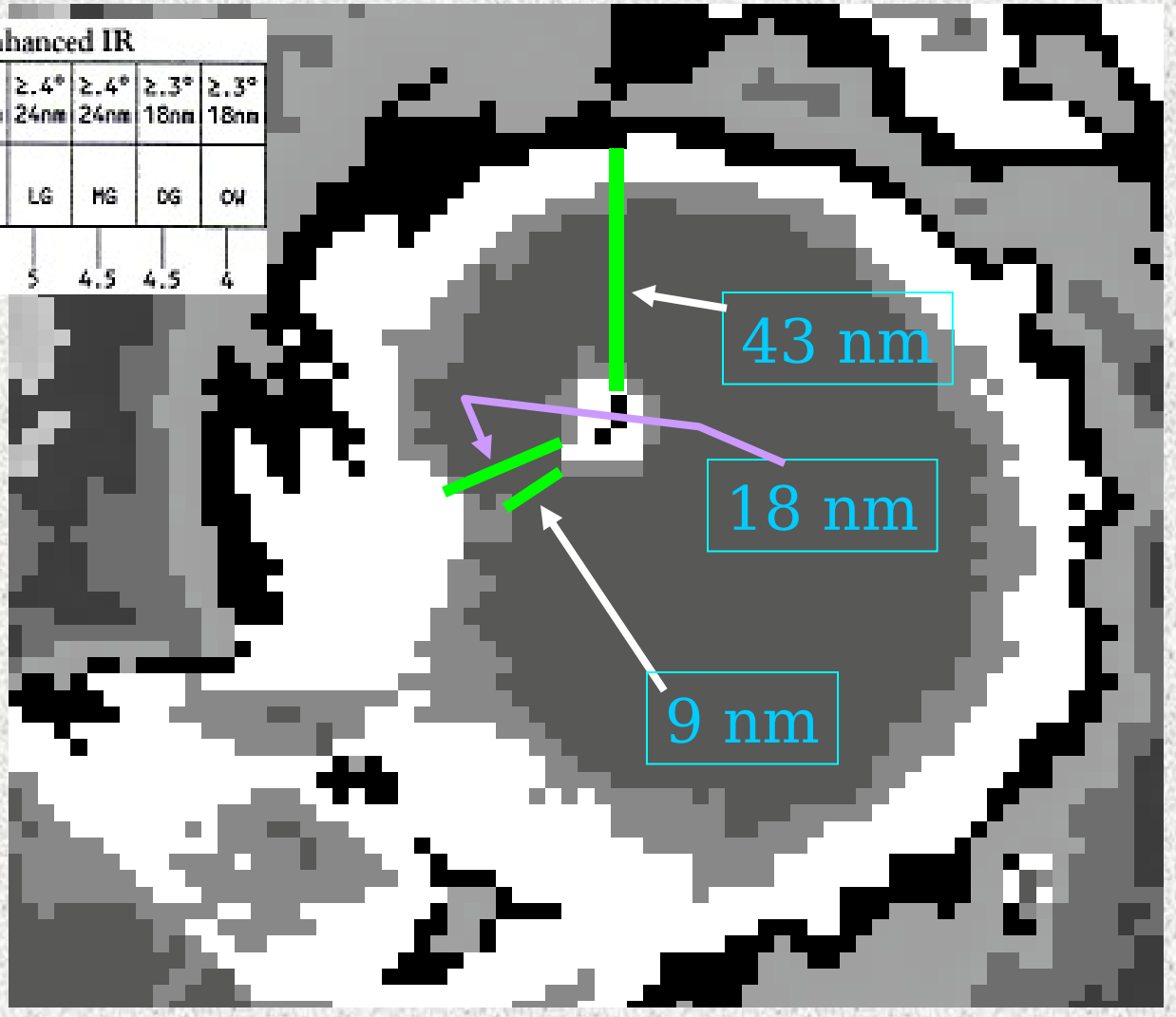
Step 2C (E# IR, Example)



Step 2C (E# IR, Example)

E# Table for Enhanced IR

Narrowest Width	≥.5° 30nm	≥.5° 30nm	≥.5° 30nm	≥.4° 24nm	≥.4° 24nm	≥.3° 18nm	≥.3° 18nm
Surround Gray Shade	CMG	W	B	LG	MG	DG	CW
E#	6.5	6	5.5	5	4.5	4.5	4



In this Example, use white ring.

The Cold Medium Gray is not wide enough (GTE 30nm)

Step 2C (Eye adj IR)

- Determine the warmest shade in the eye and the shade of the coldest ring surrounding the eye.
- Do not use for eyes 45nm diameter or larger.
- Apply to chart.

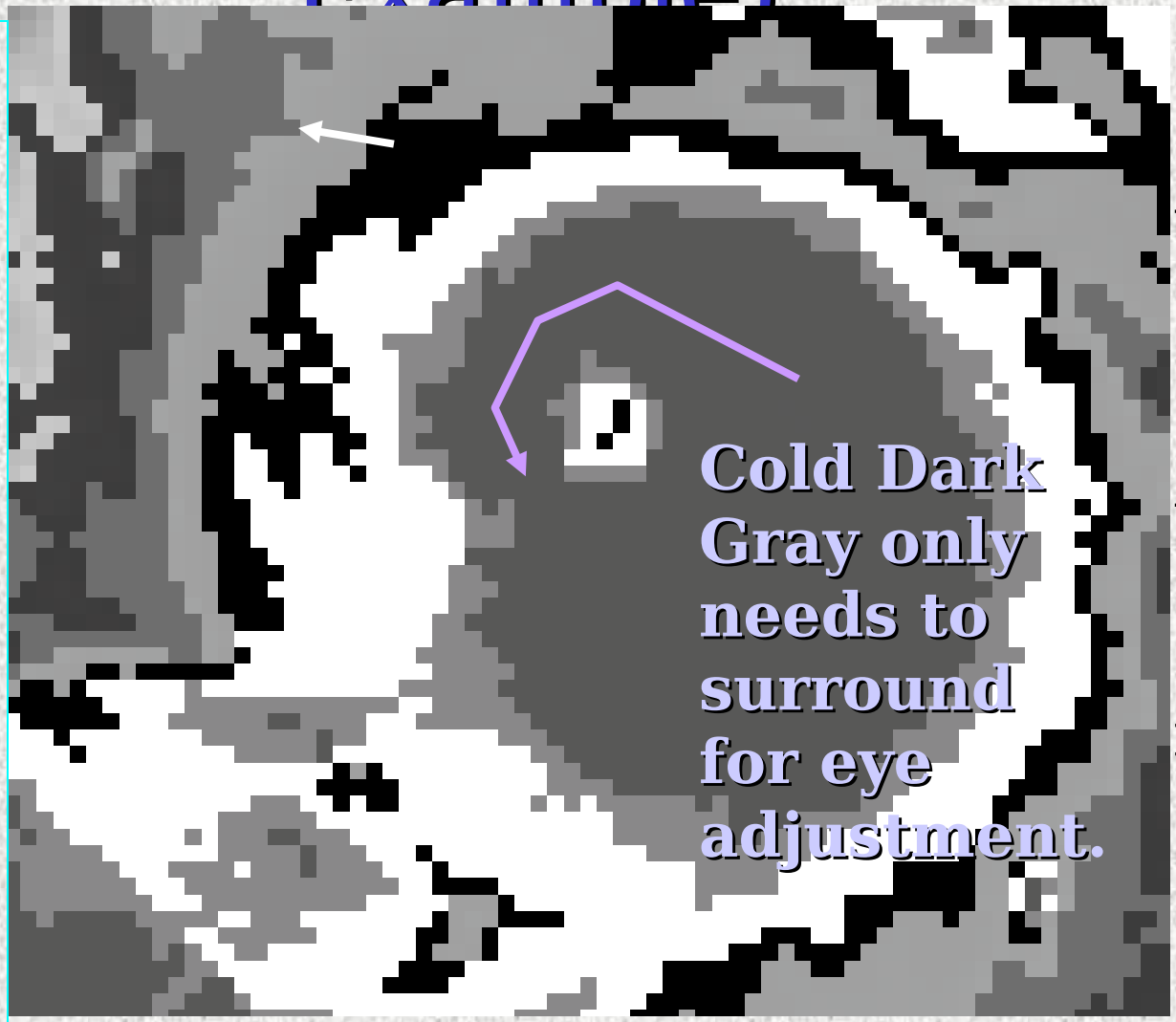
Eye Temp

Surr. Temp Ring	WMG	OW	DG	MG	LG	B	W
OW	0	-.5					
DG	0	0	-.5				
MG	0	0	0	-.5			
LG	+.5	0	0	0	-.5		
B	+1.0	+.5	0	0	0	-.5	
W	+1.0	+.5	+.5	0	0	-1.0	-1.0
CMG	+1.0	+.5	+.5	0	0	-1.0	-1.0

- For elongated eyes, subtract .5 if none subtracted by chart.

Step 2C (E Adj IR, Example)

Here, distance doesn't matter. Use the Cold Dark Gray (CDG) for the surrounding ring temp. Use Black for



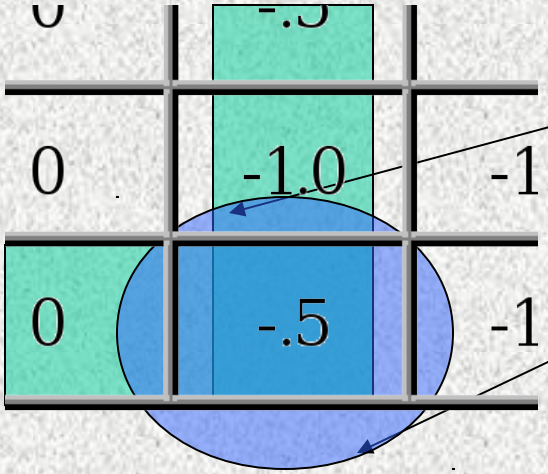
Of course the eye adjust diagram only goes to CMG, so use CMG instead.

Step 2C (E Adj IR, Example)

Eye Temp

Surround. Temp Ring

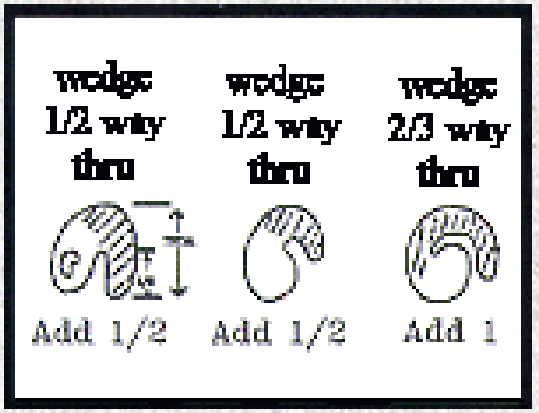
	WMG	OW	DG	MG	LG	B	W
OW	0	-.5					
DG	0	0	-.5				
MG	0	0	0	-.5			
LG	+.5	0	0	0	-.5		
B	+1.0	+.5	0	0	0	-.5	
W	+1.0	+.5	+.5	0	0	-1.0	-1.0
CMG	+1.0	+.5	+.5	0	0	-.5	-1.0



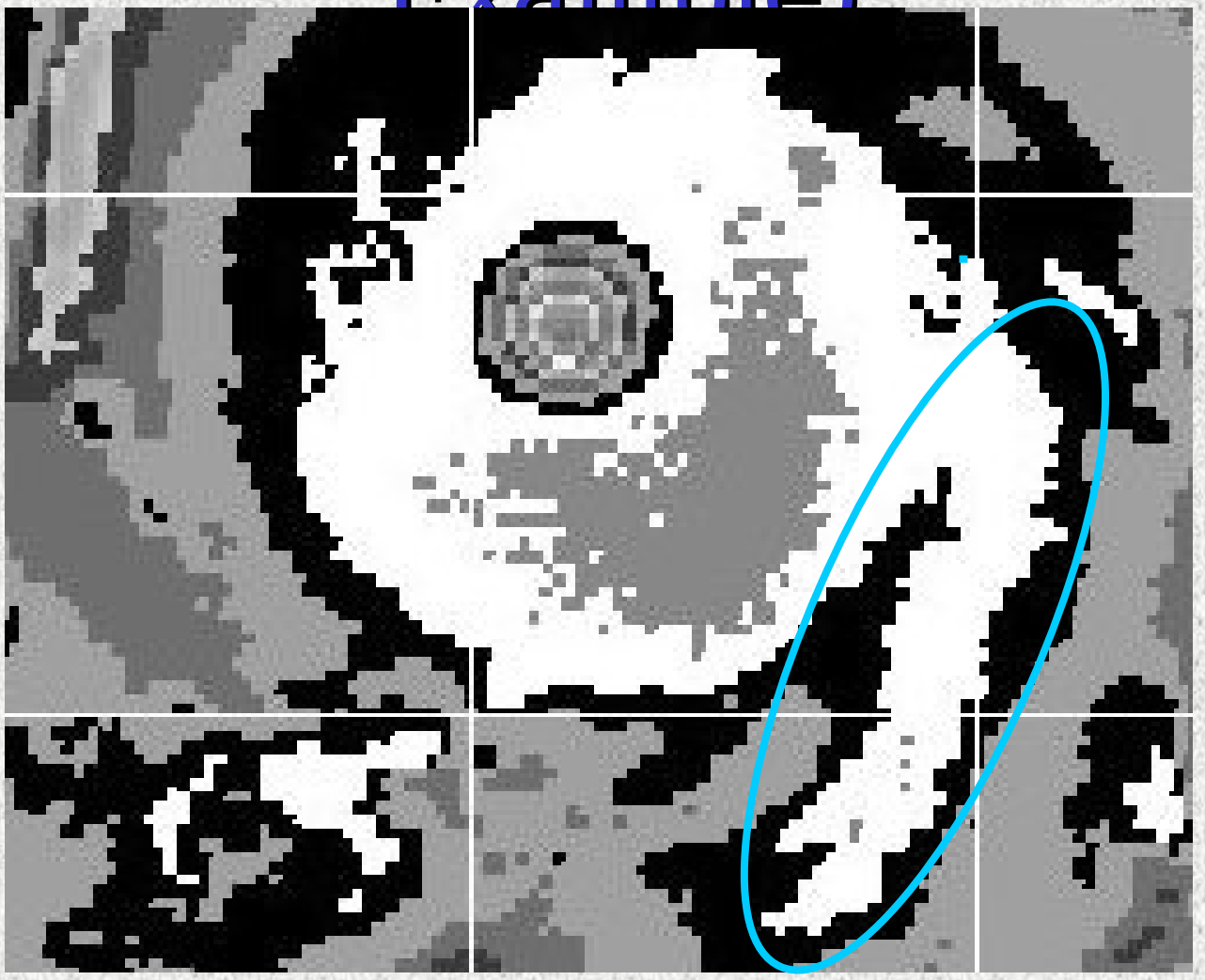
So, for a black eye and CMG surroun ring temperature, the eye adjustmen is **-0.5.**

Step 2C (BF IR)

- Use only when the CF is 4 or more and the CF is lower than the MET without adding the BF.
- Band must curve 1/4 distance around, be MG or colder, and have a DG or warmer wedge.
- Measure Wedge.
- Apply Chart.



Step 2C (BF IR, Example)



Step 2C, Eye Pattern

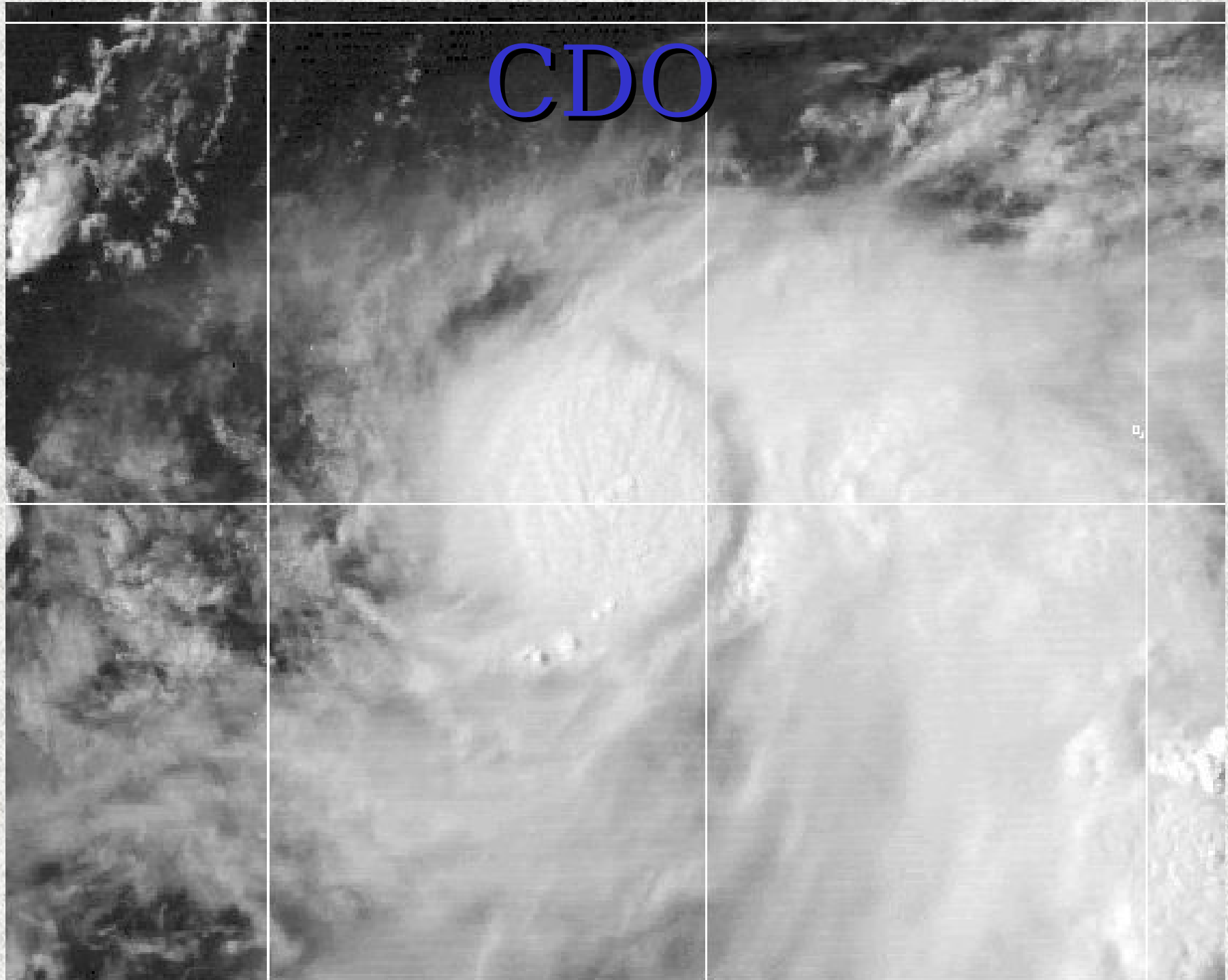
- Run the following Formulas:
  - CF Formula: CF = E# + Eye adj
  - Data-T Formula: DT = CF + BF
- When calculating with VIS, eyes with a diameter $\geq$ 30nm limit DT to 6.0 for well defined eyes, and 5.0 for all others.

Step 2D, CDO

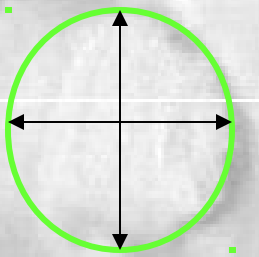
- Only used with VIS images.
- Determine if CDO is well defined.
- Measure CDO diameter and apply to chart.

Edge	Well-Defined				Irregular	
Diameter Size	>2½° 135 nm	1¾° 105 nm	1¼° 75nm	¾° 45nm	>1½° 90nm	>1° <1½° 60nm 90nm
CF#	5	4	3	2	3	2

- Add


CDO

CDO Measurement



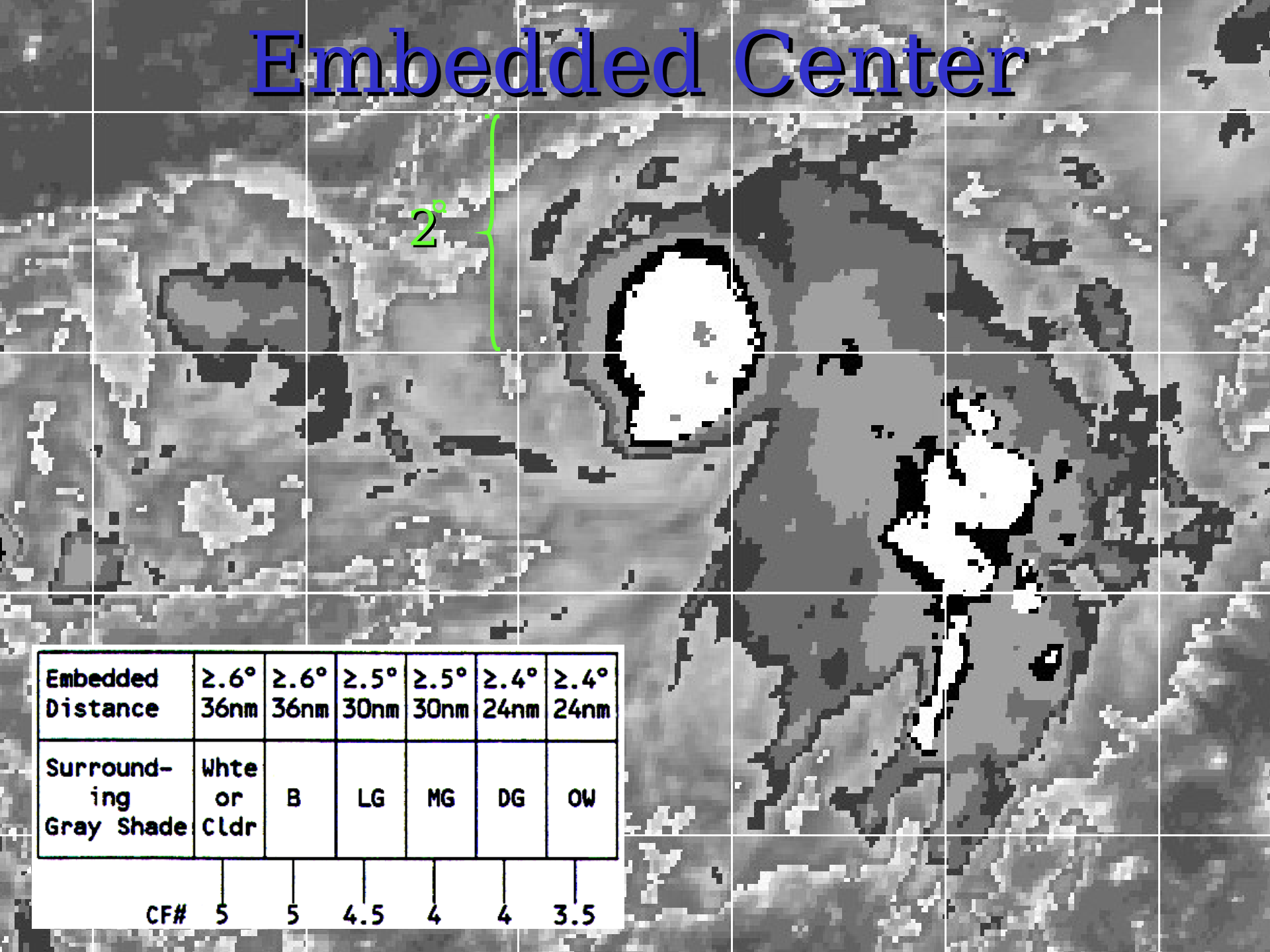
Step 2E, EMB CTR

- Only used with IR images and when Final-T from 12 hours previous was ≥ 3.5.
- Determine distance at which the center is embedded into the shades of the BD curve and apply to chart.

Embedded Distance	≥.6° 36nm	≥.6° 36nm	≥.5° 30nm	≥.5° 30nm	≥.4° 24nm	≥.4° 24nm
Surround-ing Gray Shade	Whte or Cldr	B	LG	MG	DG	OW
CF#	5	5	4.5	4	4	3.5

- Add Banding Feature.

Embedded Center



Embedded Distance	≥.6° 36nm	≥.6° 36nm	≥.5° 30nm	≥.5° 30nm	≥.4° 24nm	≥.4° 24nm
Surrounding Gray Shade	White or Cldr	B	LG	MG	DG	OW
CF#	5	5	4.5	4	4	3.5

Step 3, CCC

- Used primarily with IR imagery
- Indicates arrested development of system
- Evident by large uniform temp overcast
- When past Final-T $\leq$ 3, use MET for 12 hours then hold same.
- When past Final-T $\geq$ 3.5, hold same.
- Use as Final-T and go to Step 9

Step 4, 24-Hour Trend

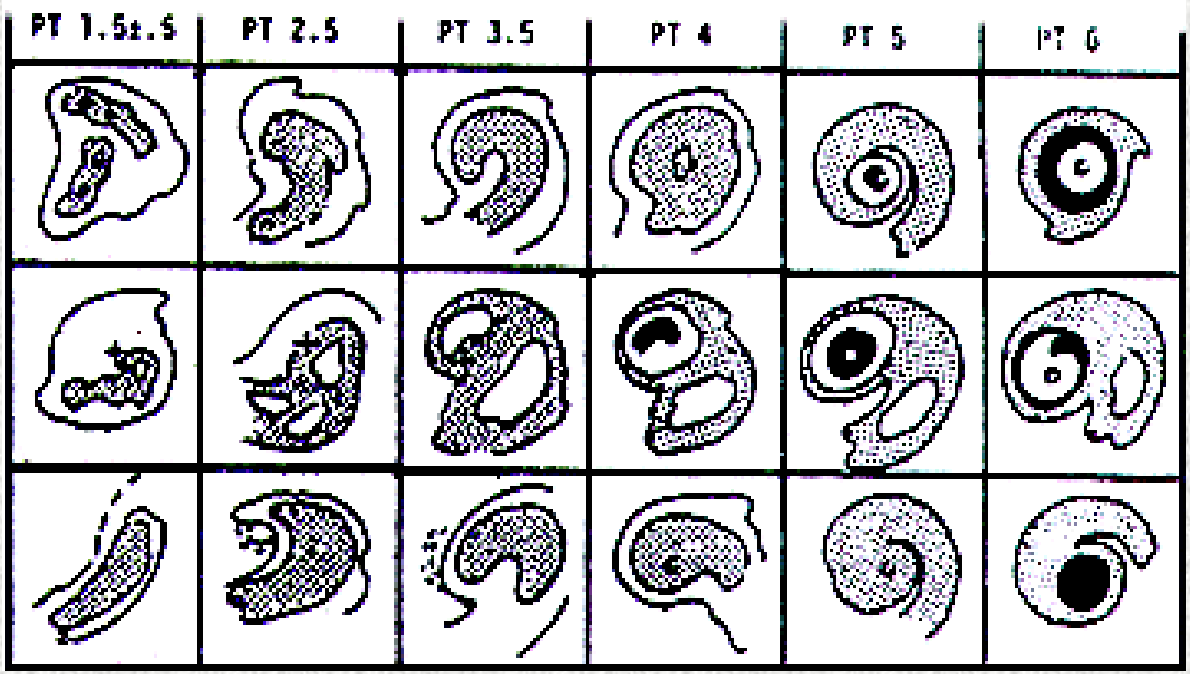
- Compare current image to image 24 hours ago.
- Determine if the cloud features in the current image look better defined, the same or worse.
  - If better, the trend is Developed (D)
  - If the same, the trend is Same (S)
  - If worse, the trend is Weakened (W)

Step 5, Model-T (MET)

- For systems with a 24-Hour Trend of D or W, determine Pattern Evolution and apply appropriate number to Final-T from 24 hours ago.
- - Slow (± .5)
- Normal (± 1.0)
- + Rapid (± 1.5)

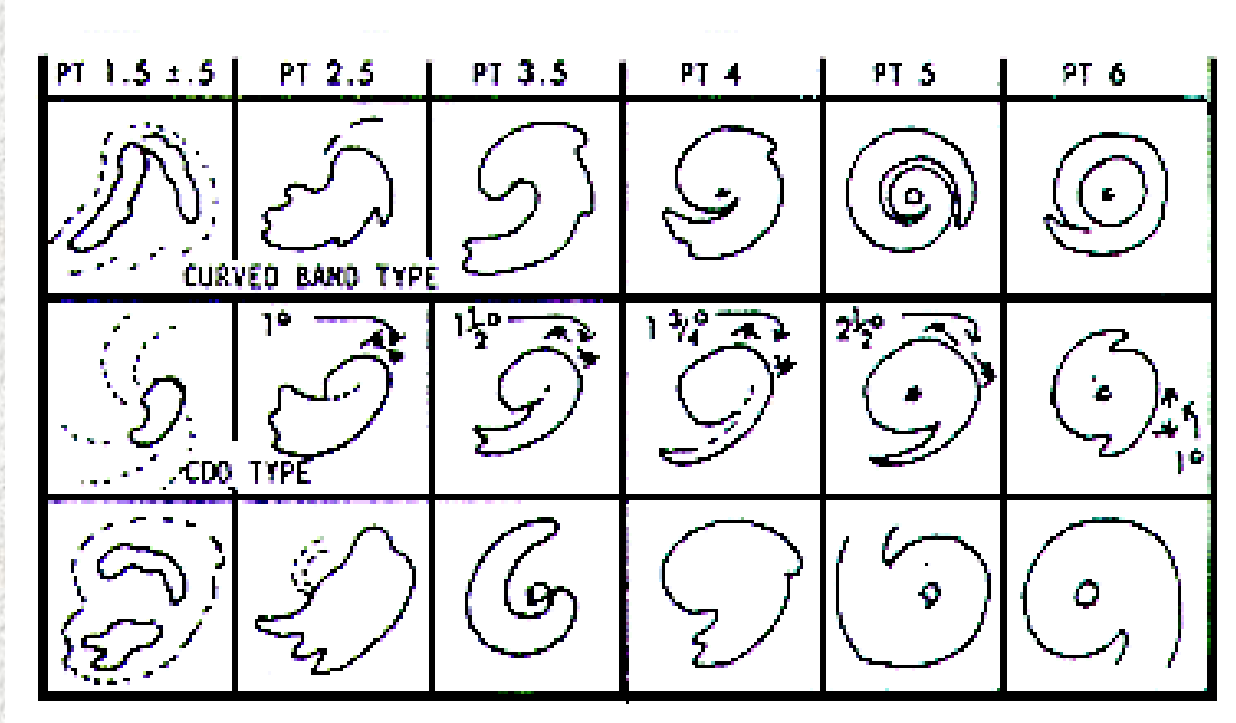
Step 6, PT (IR)

- Select the pattern in the diagram that best matches your storm picture.



Step 6, PT (VIS)

- Select the pattern in the diagram that best matches your storm picture



Step 7 - Final T-Number

- Use DT from Step 2 when cloud features are clear-cut
- Use PT from Step 6 when DT is not clear and when PT is different from MET
- For all other cases, use the MET
- Beware constraints! (Step 8)

Step 8 - FT Constraints

- **Initial classification must be T1 or T1.5**
- **During first 24?/48? Hr of development, FT cannot be lowered at night**
- **24 hr after initial T1, FT must be ≤ 2.5**
- **Modified FT limits (next slide)**
- **FT must = MET ± 1**

Step 8 - Modified FT Limits

For developing storms above T1.5 or more after the initial T1), allow a maximum change of:

- **1.0 T-Numbers over 6 hr**
- **1.5 T-Numbers over 12 hr**
- **2.0 T-Numbers over 18 hr**
- **2.5 T-Numbers over 24 hr**

Step 9 - Current Intensity Number

- **CI = FT except when FT shows a change to a weakening trend, or when redevelopment is indicated**
- **For weakening systems, hold the CI to the highest FT during the preceding 12 hr period, but <u>never</u> more than 1.0 above the current FT**
- **CI is never < FT!**

Why are there constraints?

- Weak systems sometimes lose all convection during the diurnal minimum
- Cloud patterns for weak systems sometimes look unrealistically strong
- Strong systems sometimes don’t intensify as quickly as the cloud pattern suggests
- In weakening systems, the decay of winds and pressures usually lags behind that of the cloud pattern

Dvorak Technique Output

CI Number	MWS (kt)	MSLP (Atlantic)	MSLP (NW Pacific)
1.0	25		
1.5	25		
2.0	30	1009 mb	1000 mb
2.5	35	1005 mb	997 mb
3.0	45	1000 mb	991 mb
3.5	55	994 mb	984 mb
4.0	65	987 mb	976 mb
4.5	77	979 mb	966 mb
5.0	90	970 mb	954 mb
5.5	102	960 mb	941 mb
6.0	115	948 mb	927 mb
6.5	127	935 mb	914 mb
7.0	140	921 mb	898 mb
7.5	155	906 mb	879 mb
8.0	170	890 mb	858 mb

Short Term Trend (STT)

- STT is the trend based on less than 18 hours.
- Always use a STT when you have less than 18 hours of history.
- In addition, you can use STT when the regular trend does not tell the whole story.

Rule A - Strong Unfavorable Signs in Cloud Pattern

- Persistent convective warming for > 12 hr
- CCC persisting for > 3 hr
- Signs of shear or pattern elongation
- **Forecast: No development or half of the previous development rate**

Rule B - Strong Unfavorable Signs in Environment

- Cyclone about to move into stratocumulus clouds
- Cyclone about to move onto land
- Signs of shear
- **Forecast: No development or half of the previous development rate**

Rule C - Strong Favorable Signs in Cloud Pattern

- Two successive observations of rapid development (24 hr change)
- One observation of rapid development and either a cold comma cloud pattern or multiple outflow channels
- **Forecast: If FT ≤ 5.5, forecast rapid development (1.5 T-Numbers in 24 hr)**

Rule D - Weakened Cyclone Leaving Unfavorable Environment

- Cyclone leaving conditions from Rule B
- **Forecast rapid development to prior maximum intensity, followed by normal development**

Rule E - Cyclone Leaving Environment Where Development was Slowed

- Cyclone leaving conditions from Rule B
- **Forecast previous rate of development**

Rule F - Developing Cyclone Leaving Unfavorable Environment

- Cyclone leaving conditions from Rule B
- **Forecast increase of 1 T-Number per day in rate of development**

Rule G - Cyclone Peaking

- Northward moving cyclones expected to peak 4 days after first T1
- Westward moving cyclones expected to peak 6 days after first T1
- All other cyclones expected to peak 5 days after first T1
- **Forecast no change in intensity**

Rule P - Persistence

- Use when no strong signals are present
- **Forecast trend from past 24 hr to continue**

Rule L - Large Eyes

- For eyes 30 nm wide or larger with FT ≥ 6.0 limit FI to 6.0

What to do if the system is over land?

- As a rule, don’t classify systems over land
- There are a few (subjective) exceptions to the rule if the cyclone is close to the coast or over small islands
- If the system moves back into the water, re-start classifications using the observed DT or PT

Questions?